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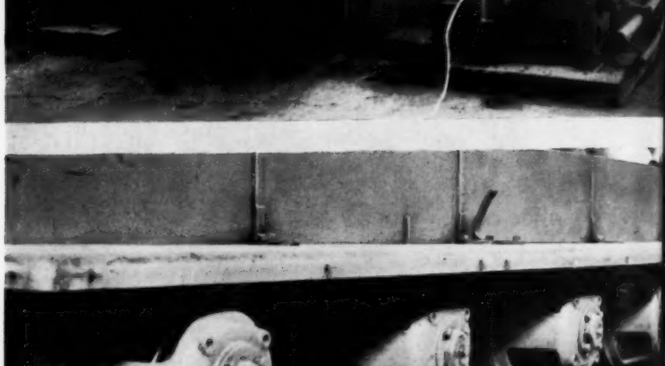

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By CHARLES W. E. CLARKE
Consulting Engineer
United Engineers & Constructors, Inc.
PHILADELPHIA

Presented before the A. I. & S. E. Annual Convention, Chicago, Illinois, September 28, 29, 30, October 1, 1938

▲ INDUSTRIAL power demands, particularly those of the Steel Industry, are fast assuming proportions which put the industrial plant more or less in the class of some of the Utility plants. As an instance, Ford Motor Company have in operation today two 110,000 kw. units, operating on 1,250 lb. pressure. One unit operates at 900 deg. F. without reheat and the other at 725 deg. F., with reheating to 725 deg. F. There is an additional unit on order for 1,250 lb., 900 deg. F.

In the Steel Industry the introduction of modern rolling methods is accounting for a very rapid increase in power demands and it will not be long before the larger steel companies will have use for units with capacities of about 50,000 kw. With this in mind it is more or less natural that we should look to the modern developments of the Utilities as a guide to what can be done for industrial plants in the way of obtaining both reliability and efficiency.

GENERAL

In the past ten years there has been a tremendous development in the power plant field. Boiler pressures, steam temperatures and sizes of boilers and generating units have increased enormously. Pressures in the last twenty years have increased in general from about 250 lb. to 1,400 lb., as is shown in Figure 1. The flattening out of the curve indicates the period during which the profession is becoming familiar with these relatively high pressures, after which there will no doubt be a further increase in operating pressures, limited only by the economic value of such increase. There are one or two installations operating or proposed which are far beyond the highest pressure shown on the curve. The highest of these will be referred to later in more detail.

During a like period steam temperatures have increased from about 650 deg. F. to 950 deg. F. total final temperature. Figure 2 shows this increase in final temperature over the last thirty years. Another distinct flattening of the curve is noticeable at about 940 deg. F. at which point we are again limited by commercially available materials. While, theoretically, a further increase in steam temperature would result in an increase in the thermal efficiency of the turbo-generator, it is doubtful whether the cost of such an improvement could be justified economically.

In 1915 a boiler with a steaming capacity of 100,000 lb. per hour would have been considered a very large unit. Today boilers of 750,000 lb. to 1,000,000 lb. per hour capacity are not rare and capacities as high as 1,250,000 lb. per hour have actually been obtained from existing units. This increase is shown in Figure 3. It is highly improbable that units of 1,250,000 lb. per hour will ever be generally used as this size is certainly approaching the condition of "too many eggs in one basket".

In the case of turbines, twenty years ago a 15,000 kw. unit was considered a large unit. By 1920 this had been increased to about 50,000 kw. and today units of 100,000 kw. are in general use, while there are several units in actual operation of from 160,000 kw. to over 200,000 kw. capacity.

CHARLES W. E. CLARKE

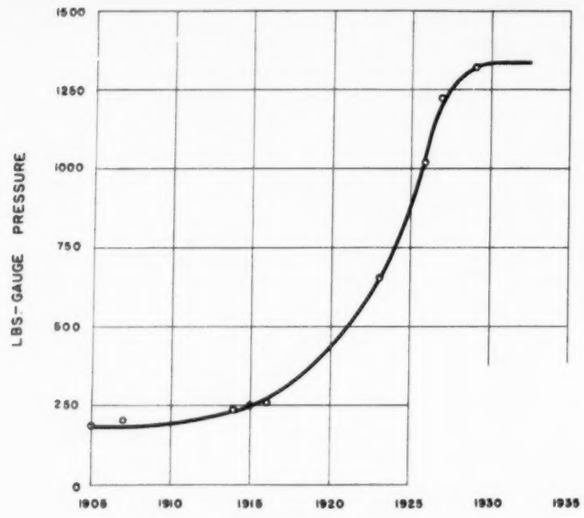
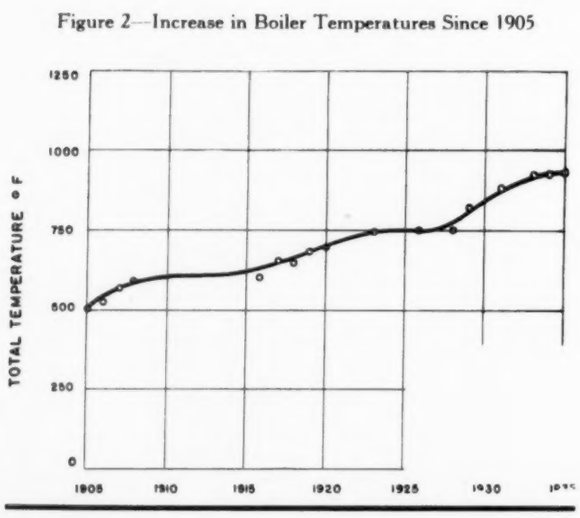


Figure 1—Increase in Boiler Pressures Since 1905

In general the larger the steaming or generating unit installed, the lower in cost the installation becomes per kw. capacity. This has been one of the principal incentives for the utility industry to use larger units. For the same pressure a boiler of 100,000 lb. capacity costs about twice as much per 1,000 lb. output as does a 1,000,000 lb. boiler. Generating units operating at 3,600 rpm. are being built as large as 50,000 kw. and manufacturers are at present giving consideration to going as high as 75,000 kw. at this speed. This applies particularly to compound condensing units. It is interesting to note the comparative size and weight of two turbine rotors of the same capacity at speeds of 3,600 and 1,800 rpm. The 3,600 rpm. rotor is 80″ in diameter over the last blades, 6′-5″ long and weighs

Figure 2—Increase in Boiler Temperatures Since 1905



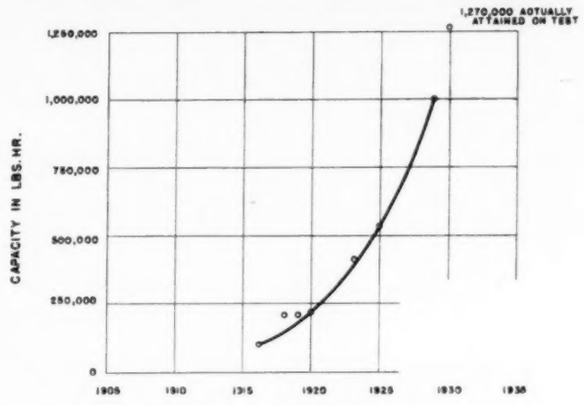


Figure 3—Increase in Boiler Capacities Since 1905

23,000 lb., while the 1,800 rpm. rotor is 110″ in diameter over the last blades, 8′-0″ long and weighs 108,000 lb. Figure 4 shows the tremendous increase in size of turbo-generator units during the last fifteen years.

Coincident with these changes there has been a substantial increase in the overall efficiency of the generating plant. With the steam cycle of today it is entirely feasible to obtain overall plant thermal efficiencies of about 30%. Ten years ago 23% would have been considered excellent performance. Figure 5 shows how the Btu. rate per net kw-hr. has decreased over a period of years. This applies specifically to a large Utility System. Figure 6 indicates the reduction in average coal consumption and corresponding growth of installed capacity in the entire Utility industry.

These tremendous advances have been made possible by several factors:

1. The development of chrome, nickle and molybdenum alloys has allowed a construction (in machines, piping connections and other pressure parts of the generating plant) which copes with the increased stresses and which permits safe use of the high pressures and temperatures which have developed.
2. Improvement in welding and manufacturing processes. The highly developed welding art has been extremely effective in promoting efficient production not only of boiler parts but of piping systems also, allowing the welding-in of valves and obviating the need for flanged joints which, under the higher temperatures, are apt to require considerable maintenance due to the creep stresses in the joint bolting material.
3. Better knowledge of the physical properties of steam.

The influence of increased pressure and temperature on heat consumption of the turbo-generator and on the station heat rate per net kw-hr. is illustrated by Figure 7. It will be noted that while the prime mover in itself continually attains better efficiency with increased pressure and particularly with the higher temperature, the overall plant efficiency, assuming 1,000 deg. F. as being present-day maximum allowable temperature, shows little or no gain to be expected above 1,400 lb. unless

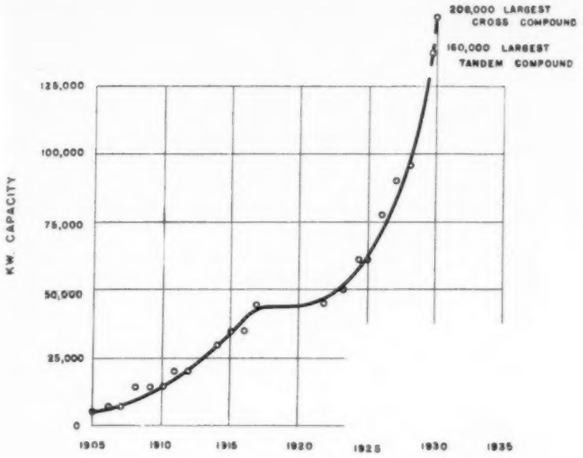


Figure 4—Increase in Turbo-Generator Sizes Since 1905

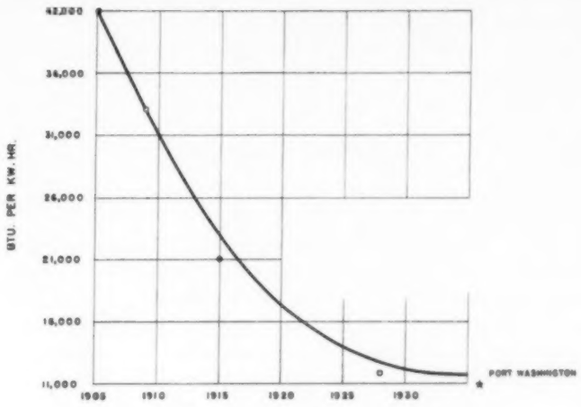


Figure 5—Improvement in Heat Rates Since 1905

reheating is resorted to for these higher pressures. The difference in the shape of the curve for the turbine as against the complete plant is due to the requirements of the auxiliaries, particularly the power needed for pumping feed water.

One of the pioneers in the use of steam pressures above 1,000 lb. is The Milwaukee Electric Railway and Light Company, which commenced using 1,300 lb. pressure in their Lakeside Plant in 1926. This Company has recently installed additional capacity in a new plant at Port Washington which operates on a reheat cycle at 1,300 lb. pressure, 825 deg. F. temperature. The steam after passing part way through the high-pressure cylinder is reheated to 825 deg. F. by radiant surface located in the furnace of the 690,000 lb. capacity boiler and is returned to the turbine for expansion to the surface condenser. The moisture content of the steam entering the condenser is only 8% when operating at 62,000 kw.-1 in. Hg. back pressure.

The turbo-generator has a capacity of 80,000 kw. and all the steam is supplied by one boiler. The plant was put into operation on September 19, 1935, and has performed very satisfactorily. The average heat consumption for some months has been 10,900 Btu. per net kw-hr.; this is a thermal efficiency of 31%, the highest ever reached for the steam cycle. Figure 8 shows a cross section of the turbine, including outlet and inlet for reheating of the steam. The cross section of the boiler is shown in Figure 9.

BOILERS

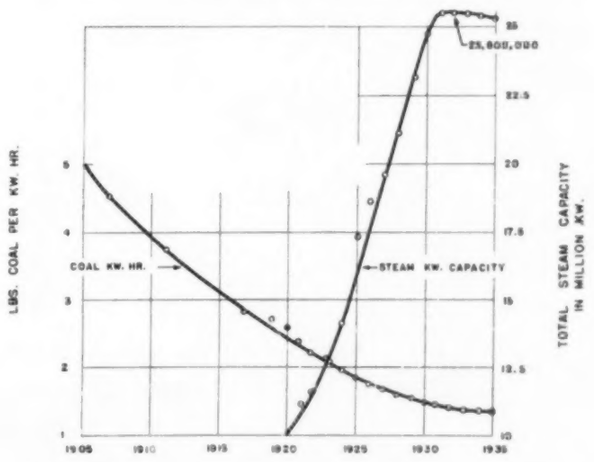
The increase in steaming capacity, steam pressure and steam temperature has caused many changes in boiler design. In this country these changes were not fundamental, but consisted rather in rearrangement of heat absorbing surface, the use of water-cooled walls, superheat control, welded steam drums, air preheaters, pulverized coal, new ways of removing ash and similar changes to parts of the steam generator. Steam drums and thermal water circulation are still used almost without exception.

FURNACE WALLS

The steaming capacity of modern boilers with coal consumption running as high as 60 tons per hour, requires not only large combustion space, but also has made it advisable to increase the heat release per cubic foot of furnace volume, especially on the larger units. About 1923 the first commercial installation of water-cooled furnace walls was made in the Sherman Creek Plant of The New York Edison Company. This development has become widely used and today boiler walls with refractory surface are rare except in particular cases where refractory materials are necessary, due either to the low operating load of the unit or to some special character of the fuel.

Refractory walls have always been subject to considerable maintenance and the water-wall development was preceded by an intensive development of air-

Figure 6—Increase in Steam Generating Capacity Since 1920 and Improvement in Coal Consumption—Entire Utility Industry



cooled walls which, while mitigating many of the difficulties of the solid wall, did not entirely obviate the troubles. The advantage of the water-cooled walls is that, while protecting the wall structure and reducing maintenance, they also permit a considerable heat absorption and steam generation in the wall surface.

SUPERHEAT CONTROL

Due to the limitations imposed by the metals used in superheaters, piping and turbines it is of great importance that under high-temperature operating conditions the design temperatures be not exceeded, while steam economy requires that the steam be held as near as possible to the turbine design temperature. In, order to maintain a nearly constant steam temperature the following means have been employed:

1. Combination of convection and radiant-type superheaters. Since the convection-type superheater produces steam temperatures which increase with load, and the radiant-type superheater produces steam temperatures which decrease with load, passing the steam successively through convection and radiant superheaters, each properly proportioned, will result in a temperature nearly constant at all normal operating loads. Combination convection and radiant superheaters are used at the Port Washington Plant as shown in Figure 9.
2. The convection-type superheater can be installed in two sections. After the steam has passed through the first section, all or part of it can be passed through a heat exchanger connected to the boiler circuit and reduced in temperature before it passes through the second superheater section. The quantity of steam thus cooled is regulated to maintain a constant superheater outlet temperature. Figure 10 shows an installation with this type of superheat control at the Buzzard Point Station of Potomac Electric Power Company.

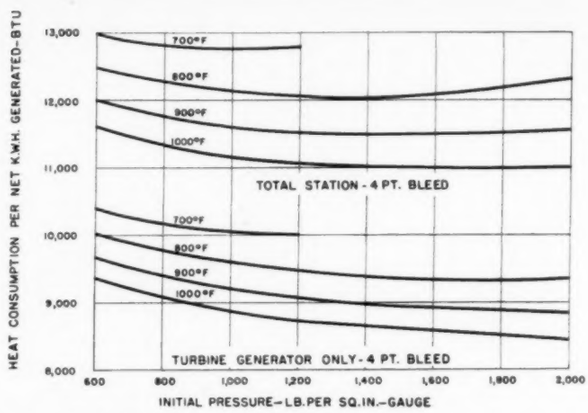
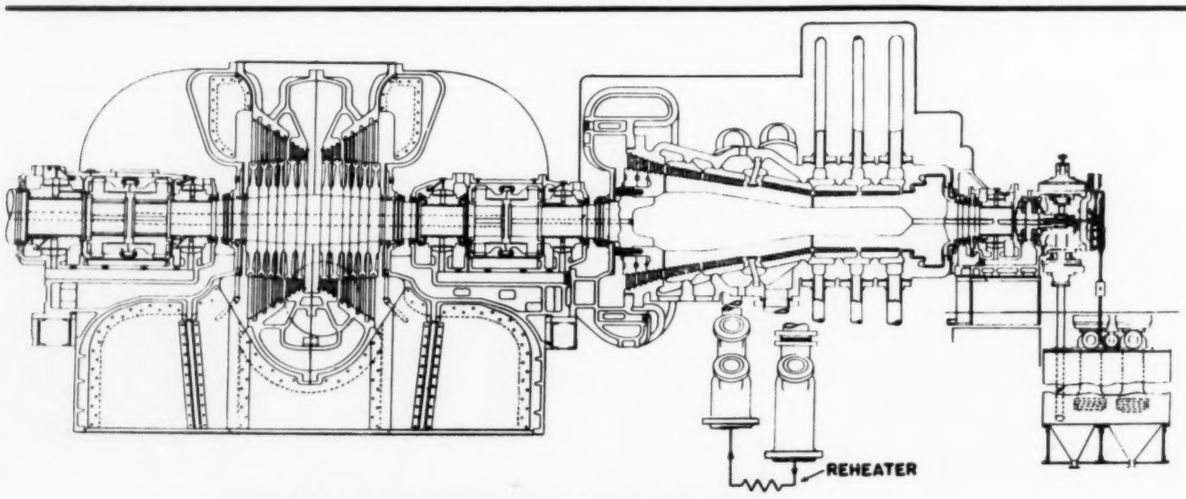


Figure 7—Attainable Heat Rates With Higher Pressures and Temperatures

3. Controlling the quantity of flue gas passing over the superheater. Baffles and dampers are installed in the convection surface of the boiler in such a way that the gases may all be passed over the superheater or, by manipulation of dampers, part can be diverted so as not to impart its heat to the superheater. Figure 11 shows such an installation for a straight-tube boiler at Springdale Station of West Penn Power Company. This type of control is the one in general use today for regulating superheat temperatures.

WELDED DRUMS

As the pressures increased, the required wall thickness of steam drums became so great that the seams could no longer be riveted. Drums were then forged from solid billets, but were found to be very costly and proved a deterrent to the installation of high-pressure boilers. With the rapid advance in the art of welding



80,000 K.W. 1800 R.P.M. STEAM TURBINE UNIT
1230" GA. STEAM PRESS. 825° F. TOTAL TEMP. 825° F. REHEAT
29" VACUUM

Figure 8—Turbo-Generator Cross Section—Port Washington Station

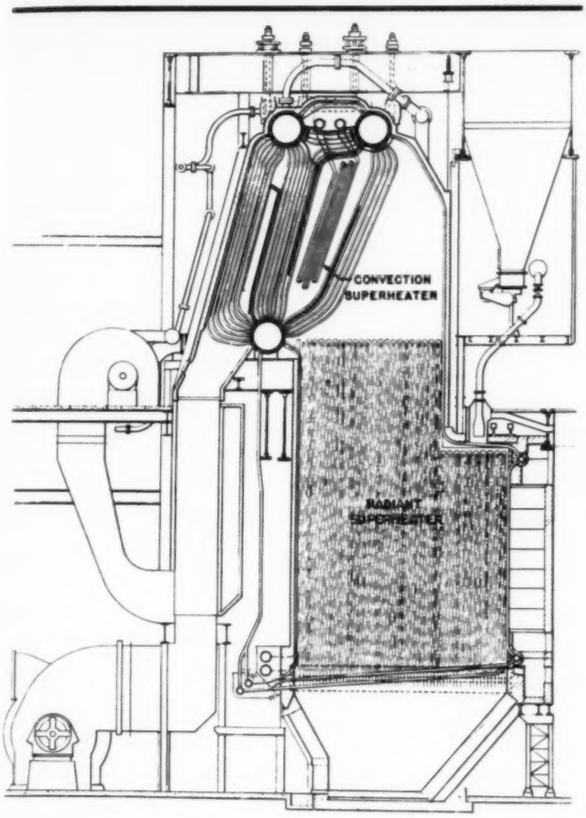
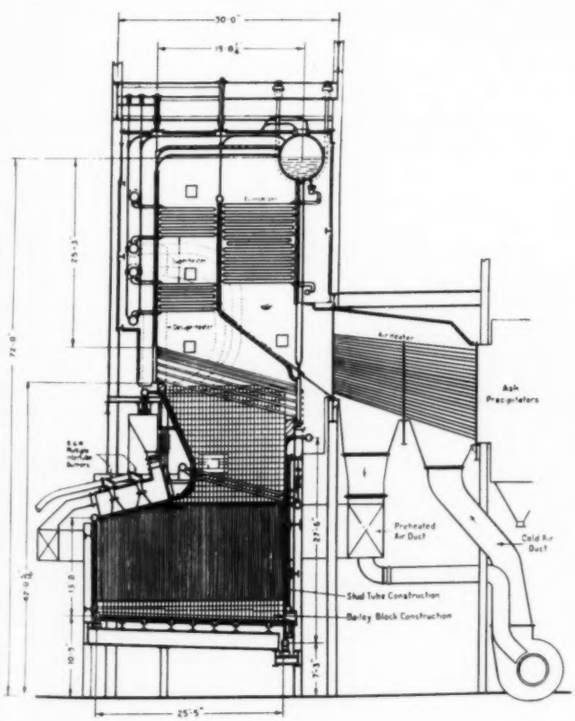


Figure 9—Boiler Cross Section Showing Combined Convection and Radiant Type Superheaters—Port Washington Station

Figure 10—Closed Wet-Bottom Furnace—Buzzard Point Station

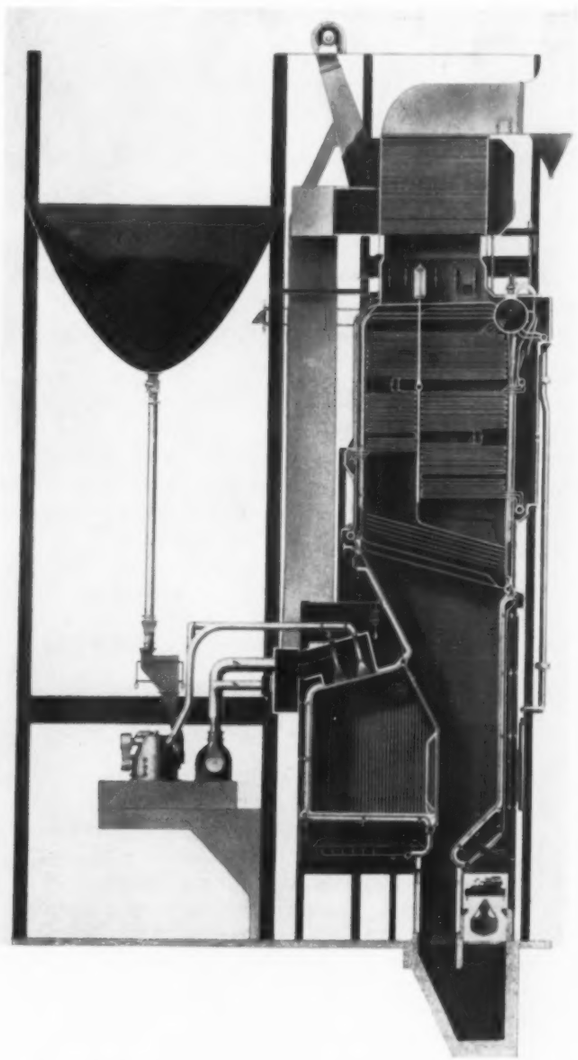


and the development of equipment for exploring welds, it became possible to construct, at reasonable cost, welded drums, which could be considered perfectly safe for boiler work. Since the rules for fusion-welded drums were adopted by the A.S.M.E. Boiler Code Committee in 1931, the use of high-pressure steam has become well established and boiler pressures of 1,400 lb. are as common today as were 400 lb. pressures ten years ago.

PULVERIZED-COAL FIRING

Burning coal in pulverized form has made rapid strides. Twenty years ago it was hardly heard of in the power field while today the majority of medium-size and larger plants are designed for pulverized coal. Reports from the three principal boiler manufacturers

Figure 11—Closed Wet-Bottom Furnace—Superheat Control by Dampers—Springdale Station



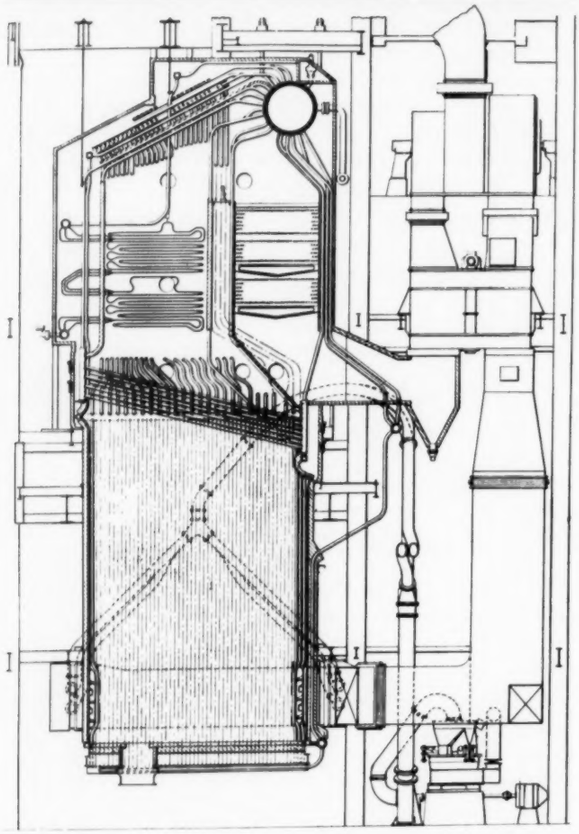


Figure 12—Open Wet-Bottom Furnace Tangentially Fired with Self-Contained Forced and Induced Draft Fans—Waterside No. 2 Station

show that of 335 boilers installed in the last five years, of 100,000 lb. per hour capacity or above, 182 were pulverized-coal-fired, 67 were stoker-fired, 60 were fired with gas or gas and oil and 26 were fired with mixed fuels, pulverized coal, gas and oil. This advance is directly traceable to the innate advantages of pulverized fuel. We list a few:

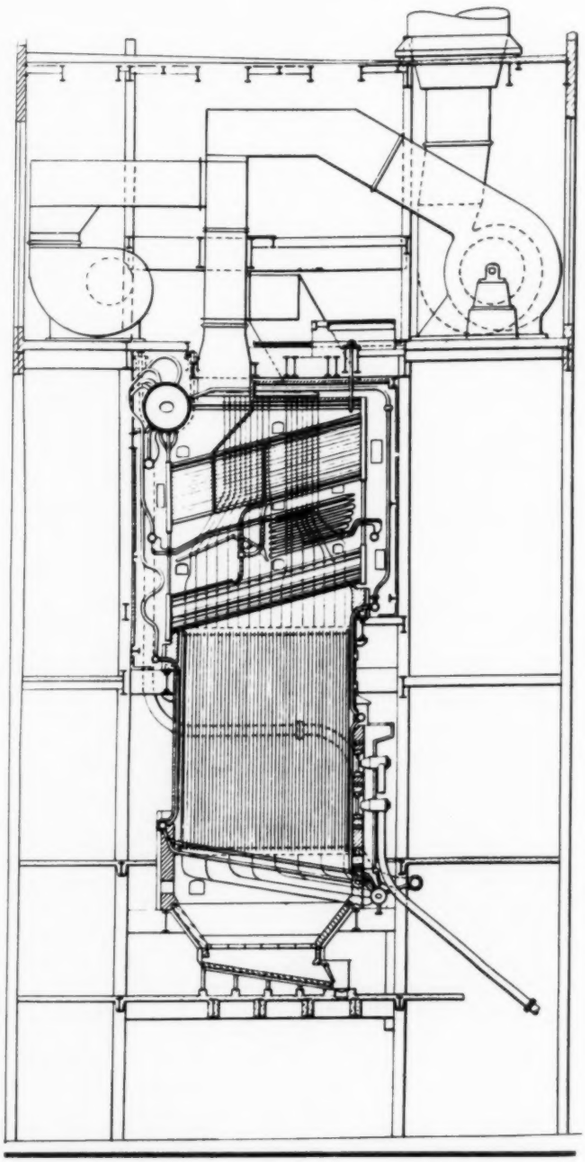
a. Pulverized coal can be applied to boilers of any size, whereas the boiler size is limited by stoker firing.
b. Poorer grades of coal can be burned better in pulverized form.
c. Boilers can be kept on the line longer, since the combustion equipment is entirely outside the furnace.
d. Higher air temperatures can be used.
e. Pulverized coal can be readily burned in combination with other fuels such as blast-furnace gas, coke-oven gas, natural gas and oil. This latter point must appeal to the Steel Industry.

In order to get a more nearly homogenous mixture of fuel and combustion air, corner or tangential firing is gaining in favor. It produces a high degree of turbulence in the furnace which is particularly desirable when the combustion rate per cubic foot of volume is high. Figure 12 illustrates this arrangement of burners at Waterside No. 2 Station of The New York Edison Company.

One disadvantage of using pulverized coal in or near Populated areas is the problem of fly ash, as nearly one half of the ash from pulverized coal passes through the boiler and out the stack unless fly ash catchers are installed to remove it from the flue gases. Electrostatic precipitators have been used almost exclusively in the past for this dust elimination but, of late, equipment based on the principle of centrifugal force has been improved to such an extent that it is performing satisfactorily for fly ash removal. Both types of equipment are expensive, especially the electrostatic type, and they do not earn any return on the investment.

There are two types of furnace bottom in general use with pulverized fuel firing. One is the so-called dry-

Figure 13—Dry-Bottom Furnace Installation—Burlington Generating Station



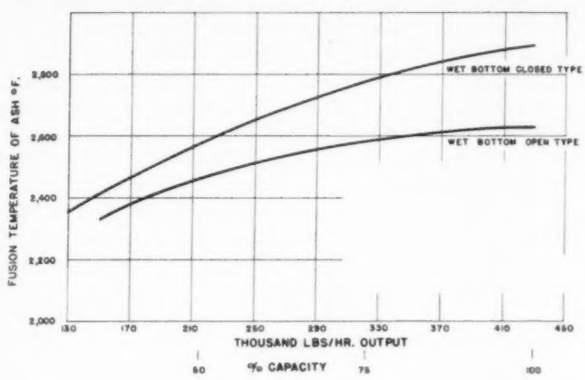


Figure 14—Limited Ratings with Wet-Bottom Furnaces

bottom which disposes of the pulverized fuel ash in dry granular form. This bottom is composed either of hoppers with water-cooled covering to solidify or granulate the ash or has installed, across the top of the ash hopper, a slag screen through which the molten ash passes and, due to the lower temperature, solidifies or granulates. This design of furnace bottom is particularly advantageous for coals with ash of high fusion temperature. However in properly designed installations it can be used successfully with almost any type of coal. This construction is shown in Figure 13, an installation at the Burlington Generating Station of Public Service Electric and Gas Company.

The other type, the so-called wet-bottom furnace, is a furnace wherein the temperature in the furnace combustion space is kept high enough to liquefy the ash. This type of furnace is particularly applicable to the poorer grades of coal although there are a number of installations where it has been used with coals having an ash fusion temperature as high as 2,700 deg. F. The wet-bottom furnace has some advantages, one being that it does entrain a certain amount of fly ash which would escape from a boiler with a dry-bottom, but it also has distinct limitations in the ratings at which the boiler can be operated, particularly in the lower operating ranges and when using fuels with ash fusion temperatures of 2,300 deg. F. and above. This is shown in Figure 14 which gives operating data for two types of wet-bottom designated as "closed" and "open."

It will be interesting to trace the development of the closed-type wet-bottom. The installation at Richmond Station of Philadelphia Electric Company, shown in Figure 15, is one of the forerunners of the closed wet-bottom and consists of a vertically fired unit with a water screen across the top of the combustion space considerably below the boiler heating surface, more or less isolating the combustion space from the furnace proper.

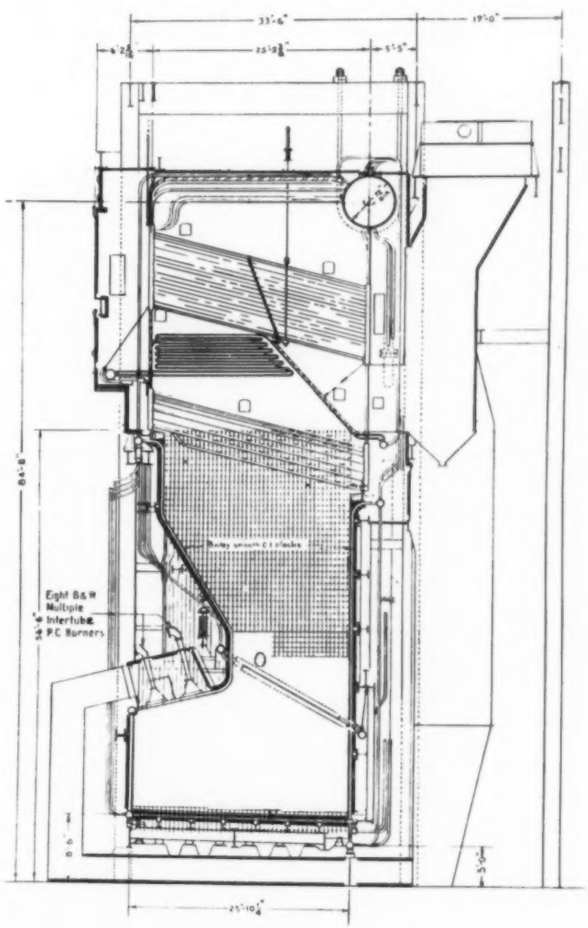
Successive changes brought this to a real closed-type as shown in Figure 16, Fisk St. Station, Commonwealth Edison Company, where the slag screen has been placed vertically.

Figure 17 illustrates the same general type of furnace construction with a very different arrangement of boiler convection and radiant heat surfaces. This unit is installed in the West End Station, Cincinnati Gas and Electric Company. It was designed primarily to be installed in an existing station where head room was restricted and is at present operating on coal with ash fusion temperatures as high as 2,700 deg. F. This particular type of design is based on heat liberation in the primary furnace of from 80,000 to 90,000 Btu. per cu. ft. per hour.

A typical open-bottom furnace is illustrated by Figure 12.

Originally this "wet-bottom" slag was tapped off intermittently, but continuous tapping seems to be coming into favor now. The pool of molten slag, always present on the furnace floor with intermittent slagging, constitutes a hazard. It is sometimes difficult to start the slag running and there have been a number of cases where slag has actually broken through the furnace floor. Continuous tapping eliminates this trouble.

Figure 15—Partially Closed Wet-Bottom Furnace—Richmond Station



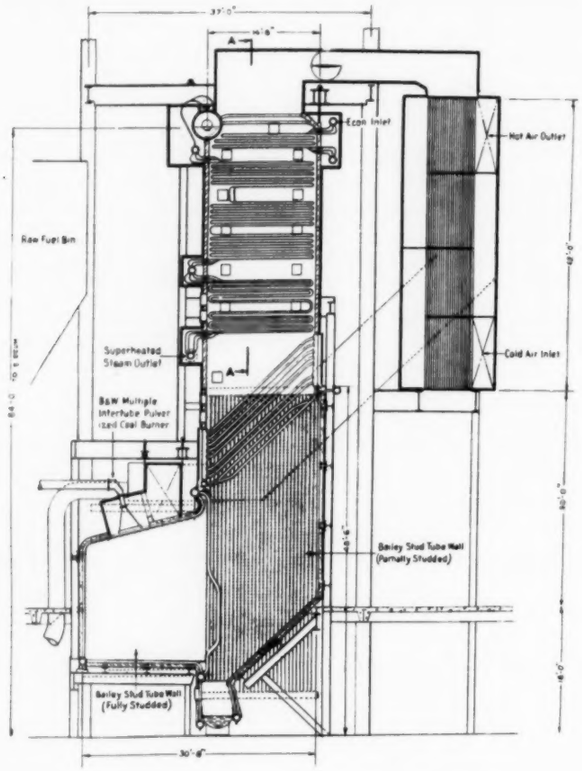

Econ Inlet
Hot Air Outlet
Raw Fuel Bin
Superheated Steam Outlet
Cold Air Inlet
Babcock Multiple Interfuse Pulverized Coal Burner
Bailey Stud Tube Wall (Partially Studded)
Bailey Stud Tube Wall (Fully Studded)

Figure 16—Closed Wet-Bottom Furnace—Fisk Street Station

In removing the slag from a slagging-bottom furnace, the molten mass is passed through a series of water sprays for cooling and for disintegration, and is then sluiced by high-pressure water jets to a pit from which it may be pumped to the point of disposal. With intermittent tapping, trouble was often experienced when coal of medium-fusion-temperature ash was burned; at low ratings the slag was not hot enough to flow and the boiler load had to be increased to suit slag removal. It is difficult to arrange boiler loads to agree with tapping periods.

STOKER FIRING

Although pulverized coal has replaced stoker firing to quite an extent, the stoker manufacturers have not been idle in improving their equipment. With the demand for increased boiler output it became necessary to raise the amount of coal to be burned per sq. ft. of grate area. Where formerly a combustion rate of 40 to 50 lb. of coal per sq. ft. of grate was considered the maximum, this has now been raised to as high as 85 lb. per sq. ft. for peak-load conditions. This increase in burning capacity was accomplished by better air distribution under the fuel bed, through sectionalizing the stoker wind-box. Each retort was provided with its own wind-box and each wind-box divided again into several sections. Each section was provided with a damper to control the flow of air to the grate above that section. Draft gauges were connected to each section which enabled the operator to ascertain the condition of the fuel bed above the wind-box section and adjust the dampers to the best combustion conditions. The sectionalized wind-box design has proved a decided improvement in respect to efficiency as well as stoker capacity.

Where low-fusion-ash coal must be burned at high rates, the water-cooled stoker has thus far given a good account of itself. The circulation of water through pipes placed on the tuyeres and on the ashpit walls, has reduced the troubles caused by slag adherences and the burning out of stoker parts. Figures 18 and 19 show how the water-cooling tubes are applied to the stoker.

AIR PREHEATERS

With the large water-cooled surfaces in the furnace and the large superheaters required for high steam temperatures, the actual boiler heating surface has become insignificant in comparison; the heat left in the gases after passing over the superheater is now principally recovered by economizer and air preheater surfaces. Air temperatures of 500 deg. F. leaving the heaters are not uncommon with pulverized-fuel firing and temperatures as high as 700 deg. F. have been used. An installation at Miller's Ford Station of Dayton Power & Light Company, Figure 20, illustrates the small boiler-heating surface as compared with superheater and air-preheater surface. This boiler, with a maximum output of 375,000 lb. of steam at 1,250 lb. per sq. in. pressure, has only 3,367 sq. ft. of convection surface in the boiler proper.

Air preheaters are of plate, tubular or regenerative type.. The regenerative type has an advantage in the low cost of replacing heating elements, although it is subject to leakage of air into the flue gas and is more easily plugged up with soot or fly ash on account of the small gas passages. This, of course, increases the load on the fans and makes frequent cleaning necessary. The regenerative type is particularly advantageous for higher air temperatures, as the surface required to obtain air temperatures of 500 deg. F. to 800 deg. F., with the plate or tubular type, would be almost prohibitive.

Figure 13 shows a typical plate-type air preheater layout at Burlington Station.

Figure 17 shows a typical tubular air preheater layout at West End Station.

Figure 21 shows a regenerative-type air preheater being installed in the Manchester Street Station of The Narragansett Electric Company, Providence, Rhode Island.

PROTECTION OF INTERNAL SURFACES

In spite of all the care taken to remove the oxygen from boiler-feed water, corrosion still takes place in the boiler and most operating engineers take additional precautions to prevent serious damage. A certain paint has given very good results in preventing attack on the

boiler metal providing it is properly applied. It was used as early as 1922 at the Colfax Station of Duquesne Light Company. Care should be taken when using this material to make sure that it is applied to clean surfaces, free from mill scale, grease and rust. The most vital part to be protected is the steam drum, particularly at the waterline, but boiler and economizer surfaces, including headers, are also protected in this manner. Pickling or sand-blasting the tubes and drums, before installing, greatly facilitates cleaning the surfaces to be painted.

SOOT BLOWERS

Soot blowers are still considered a necessary evil and must be used unless it is possible to take a boiler out of service frequently for hand cleaning. Most trouble with soot blowers is experienced in the hot part of the boiler setting, the continuous high temperature causing warping of the elements so that they can not be rotated. Burning off of the hangers supporting the elements is also a source of trouble as new hangers can be installed only when the boiler is down, sometimes a matter of months in the future.

If sticky slag adheres to the first bank of tubes it is practically impossible to remove it with the regular soot blowers. Hand lances for use with high-pressure water have been found effective in removing this slag, but require a considerable amount of labor. Water-cooled deslaggers are fairly satisfactory and consist of a water-cooled tube, inside of which is another tube to which the spray nozzles are attached. The space between the tubes is provided with circulating water to keep the element cool, while the water for deslagging is passed through the inner tube whenever required. The deslaggers are operated much in the same manner as regular soot blowers by rotating the element with a chain wheel. Because they are water-cooled, the deslaggers can be placed below the tube nest of the boiler without injury from furnace heat. A still later development is the telescopic deslagger, which is completely withdrawn from the furnace when not in use.

STEAM SCRUBBERS

Steam liberation in drums of high-capacity boilers is so great that despite the use of the best steam separators, some moisture is carried over into the superheater. The solid matter dissolved and suspended in this moisture is carried along with the steam and deposited in the superheater and turbine, causing tube failures and plugging of the turbine blades thereby reducing the capacity of the unit. Since the principal trouble is caused by the solids and not by the moisture, recent boiler drums have been provided with steam scrubbers designed to reduce the solids in the carry-over. These washers have a series of spray nozzles through which the boiler-feed water is admitted to the boiler, the thorough mixing of the moisture in the steam and the sprayed boiler-feed water results in a moisture content relatively low in solids. After the steam has thus been washed, it is passed through a moisture eliminator, also located in the drum. The steam at the outlet of the eliminator, though not dry, contains very few solids. Experience has shown that these washers are very effective in reducing scale troubles in superheaters and turbines. Figure 22 shows the cross section of a boiler drum with a steam scrubber.

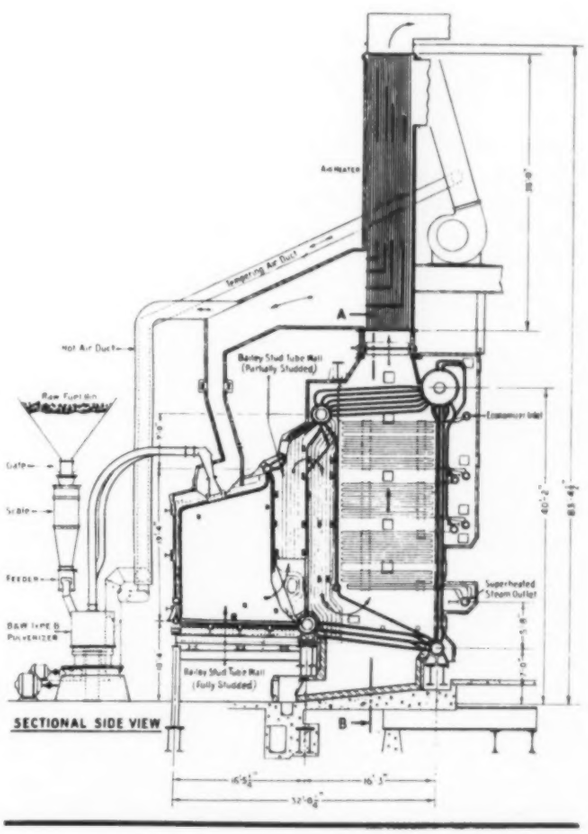
INDUSTRIAL BOILER INSTALLATIONS

The following four illustrations show interesting boiler installations in industrial plants.

Figure 23 shows a cross section of the boilers installed in 1936 by the Weirton Steel Company in their plant at Weirton, West Virginia. Two B. & W. Stirling boilers, each of 400,000 lb. per hour capacity, were installed. Steam is generated at 850 lb. and 840 deg. F. and is used by a 10,000 kw. back-pressure turbine exhausting at 215 lb. The furnace is completely water-cooled, provided with a water-cooled, slag-type bottom and arranged for firing with pulverized coal and blast-furnace gas. Raymond bowl mills supply the pulverized coal for direct firing. This plant operates on nearly 100% treated make-up water.

Figure 24 shows a cross section of the boiler now being installed in the Portsmouth, Ohio, plant of the Wheeling Steel Corporation. It has a capacity of 100,000 lb. per hour at 650 lb. pressure and 650 deg. F. The steam is used by a 3,000 kw. turbine exhausting at 170 lb. This boiler installation is somewhat along the lines of a self-contained unit, the furnace being entirely water-walled, the boiler equipped with large air preheaters and the ash from the products of combustion deposited on a flat floor at the bottom of the

Figure 17—Special Design of Low-Head Boiler—Closed Bottom —West End Station



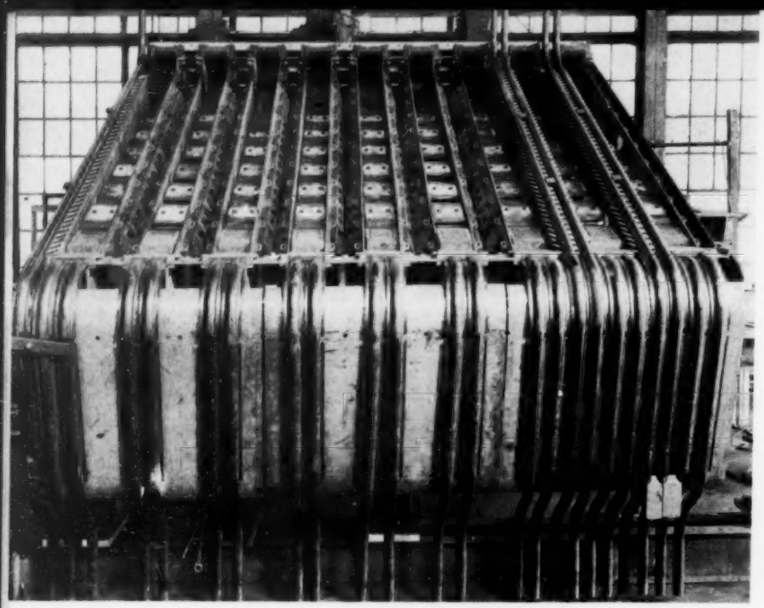


Figure 18—Typical Water-Cooled Stoker

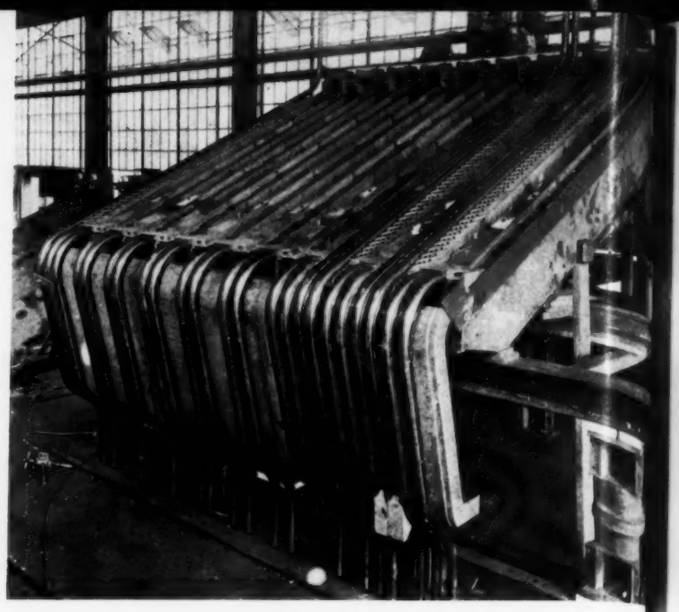


Figure 19—Typical Water-Cooled Stoker

combustion chamber and blown off by steam lances into the ashpit.

A modern stoker-fired installation at the Columbia Chemical Division of the Pittsburgh Plate Glass Company, Barberton, Ohio, is shown in Figure 25. This boiler generates 180,000 lb. of steam per hour at 900 lb. pressure and 750 deg. F. The steam is used to operate a 6,250 kw. turbo-generator bled at 400 lb. and exhausting at 140 lb. The front wall and the bridge wall are completely water-cooled. To insure protection for the side walls along the stoker fuel bed, inclined water walls, nine tubes high, with block surface, were installed. The stoker is provided with sectional air control through forty-two Venturi wind-boxes. Average daily efficiencies have been as high as 87%. This boiler operates on 100% make-up with very bad water. The concentration in the boiler is about 2,000 ppm. Small amounts of sludge accumulate in the rear tube bank but no difficulties have been experienced. This plant is now installing an additional boiler to operate under the same conditions as the first installation.

The boiler, shown in Figure 26, is designed to burn blast-furnace gas in combination with natural gas and oil and is arranged so that pulverized coal can be used later without any changes to the boiler setting. The burners are located at the four corners of the furnace for tangential firing. Three boilers of this design are now being installed in the South Works of Carnegie-Illinois Steel Company, each capable of producing 300,000 lb. of steam per hour at 450 lb. pressure and 750 deg. F. The furnaces are completely water-cooled and designed for dry-bottom ash removal. Each boiler is provided with an economizer and two Ljungstrom air preheaters. The steam is used to drive one condensing turbo-generator and three condensing turbo-blowers.

COMBUSTION CONTROL

The object of automatic combustion control is to maintain constant steam pressure, proper proportions of fuel and air supply and to reduce operating labor costs. The savings in fuel and labor with automatic control, especially for the modern large boiler, make the investment quite profitable. In fact, it would be almost an impossibility to operate large boilers properly without some form of automatic control. There are many makes of controls on the market, which have given excellent service. An interesting example is the control system now being installed in the South Works of Carnegie-Illinois Steel Company, inasmuch as it provides automatic control for multi-fuel firing. This equipment uses two systems of compressed air. One system is used to convey impulses or loading pressures which control the air flow through orifices or valves of the second system. The latter permits air to flow to devices which operate dampers, valves and other pressure-operated equipment.

The master controller which regulates the steam output of the plant is actuated from a steam-pressure device and also from a frequency device on the electric power produced. This frequency control is considered to be more sensitive to load changes than the steam pressure device, but in this instance either one can take precedence and set up an air loading pressure which will regulate fuel and air supply to maintain the steam pressure constant.

The air-loading pressure operates directly to control the air admitted to the operating cylinders attached to the dampers of the motor-driven, forced-draft fans of the three boilers, thus controlling the air supply to the furnace. The loading pressure also controls the air admitted to the operating cylinders attached to the dampers of the motor-driven, induced-draft fans and the operating cylinders of the blast-furnace-gas control valve so as to place them nearly in the proper position. The motion of the latter, however, is under additional control from the fuel-flow-air-flow meter which regulates the fuel so as to be in proper proportion to air flow. The induced-draft fan damper also has a secondary control to maintain a constant furnace draft.

Should the capacity of the motor-driven fans be insufficient, the steam-driven fans come into service automatically to help carry the load; if the blast-furnace-gas supply is insufficient, the secondary fuel

comes on automatically, be it natural gas or oil, depending on which the operator wants to use as secondary fuel.

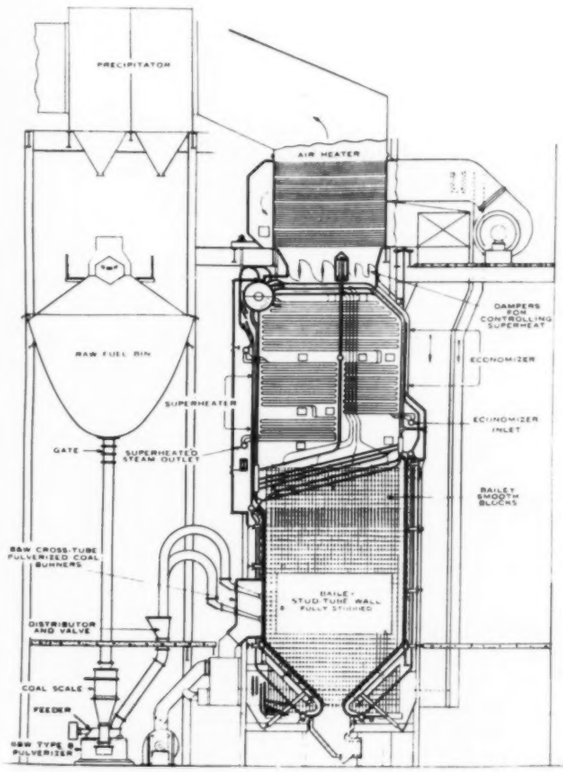
An additional control is provided which prevents the use of blast-furnace-gas when the supply is so limited that it must all be used in the process heating furnaces of the steel plant.

The operation of all combustion control equipment is centered at the boiler-room gauge board. By manipulation of the control handles on the boards the boiler operator can change from automatic to hand control of any or all boilers; he can set the load on any boiler, still maintaining proper fuel-air ratios and furnace draft; he can change the fuel-air ratio if desired; he can raise or lower the plant steam pressure; and he can make the turbine-driven fans take precedence over the motor-driven fans.

UNUSUAL BOILER DESIGNS

An interesting boiler now being installed in the Windsor Station of the American Gas & Electric Company is shown in Figure 27. The furnace of this 750,000 lb. per hour boiler is divided vertically in two sections by means of water-cooled tubes. These are part of the boiler circulation and of the same order as the water-cooled walls.

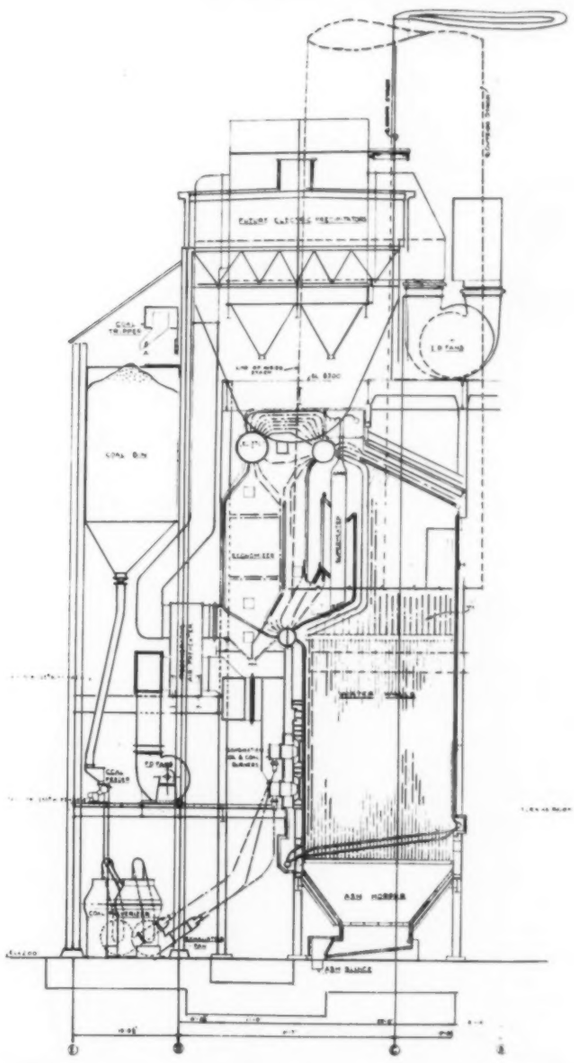
Figure 20—Dry-Bottom Furnace—Millers Ford Station



One of these sections is provided with a radiant superheater; a convection superheater is located so as to be common for both sections of the furnace. The heat release in the section with the radiant superheater is varied to maintain practically constant steam temperature of 925 deg. F. at the superheater outlet. In starting the boiler, only the section without the radiant superheater is fired, thus shielding the radiant superheater from overheating. The water-cooled division wall increases the radiant heat absorption considerably, which results in lowering the gas temperature entering the convection surface and reducing slag troubles.

The American Gas & Electric Company are also installing a new 67,500 kw. unit in their Twin Branch Plant. The steam at the throttle will be 2,400 lb. and 940 deg. F.; boiler pressure will be 2,500 lb. Figure 28 shows a section of this boiler. The unit will consist of a

Figure 21—Dry-Bottom Furnace and Vertical Regenerative Air Preheater Installation



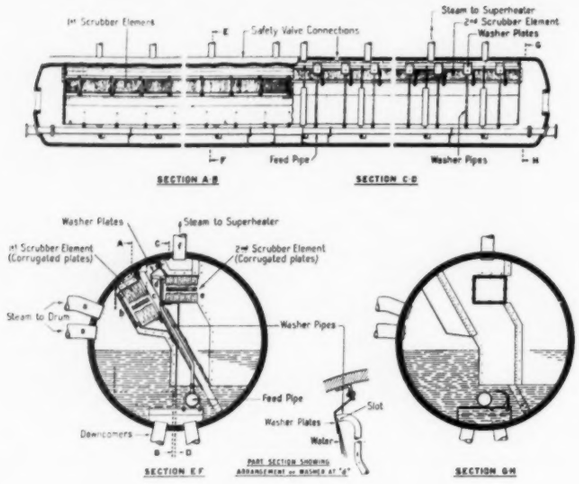


Figure 22—Typical Steam Scrubber Installation

22,500 kw. turbo-generator cross compounded with a new 45,000 kw. 400 lb. pressure turbo-generator.

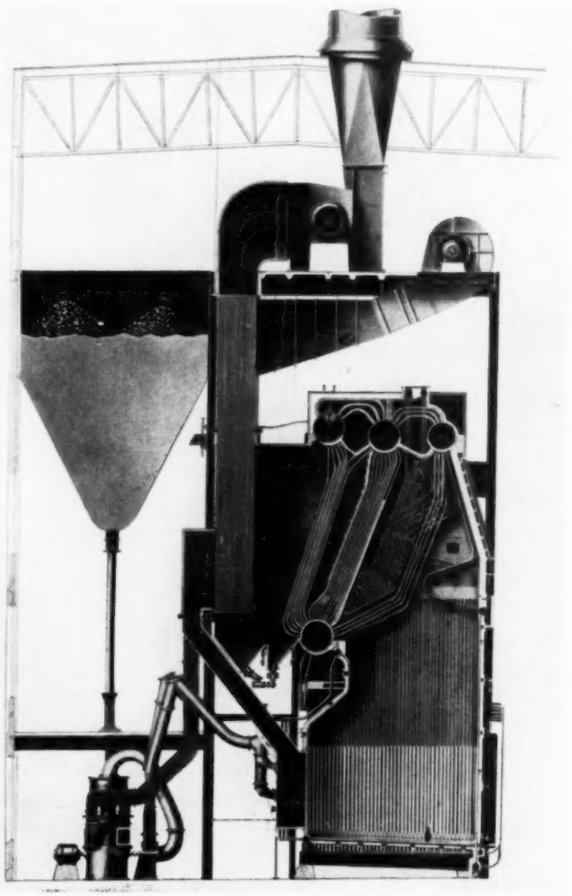
While boiler design has changed considerably in the last ten years, the usual designs brought out in Europe have not found much favor in this country. The Benson boiler with several installations on the Continent has not yet been used on this side. This boiler was originally designed to be operated at about 3,200 lb., the critical steam pressure, but modifications of the design now operate at pressures varying in accordance with the power load on the turbine. In these installations governor valves are not in operation except at extremely low loads, because governing is done by controlling the steam pressure for all loads above 400 lb. The boiler is operated on forced circulation. The output of the boiler-feed pump is also controlled from the load on the turbine. Steam temperature is maintained constant automatically. It is claimed that the heat consumption of the turbine with these varying inlet pressures is practically constant for all loads.

Another boiler of foreign design and not yet used in this country is the Loeffler boiler. In this unit the fuel is burned under a superheater. Part of the superheated steam produced is led to the turbine, while the remainder is passed through a contact heater. Here the superheat is given up to evaporate water which does not need to be pure condensate or chemically treated. The desuperheated steam and the vapor from the water are forced by a steam compressor to the superheater. This boiler design thus permits of turning untreated raw water into superheated steam, without scale formation at dangerous points. Pressure is usually about 1,800 lb. although the Loeffler boiler can be used economically from 750 lb. up. Power required for the steam compressor amounts to about 3% of the output at 1,800 lb. pressure, but the percentage becomes larger as the pressure decreases, being about 12% at 750 lb. pressure. Figure 29 shows the steam cycle diagrammatically. The Vitkovice Collieries in Czecho-Slovakia have several of these boilers, including two with a capacity of 165,000 lb. of steam per hour each.

In 1936 an 1,850 lb. Loeffler boiler was installed on the Italian steamship Conte Rosso, for a topping unit. It operates two high-pressure turbines in series, the exhaust going into the present low-pressure system.

The Velox boiler developed by Brown Boveri & Co., Ltd., of Switzerland was designed to reduce the space occupied for steam generation. It is accomplished by increasing the heat transfer rate through the boiler tubes with rapid circulation of water and combustion gases. Forced draft is introduced to the furnace at a pressure of about 35 lb. per sq. in.; the products of combustion attain velocities ranging from 450 to 900 feet per second. After passing through the boiler and superheater the gases, at 31 lb. pressure and about 900 deg. F., enter a gas turbine and exhaust at about 16.5 lb. pressure, 700 deg. F. The gases are finally passed through an economizer, leaving at atmospheric pressure and a temperature of about 200 deg. F. The gas-driven turbine is direct-connected to the blower which supplies the 35 lb. combustion air to the boiler.

Figure 23—Open Wet-Bottom Furnace—Weirton Steel Company



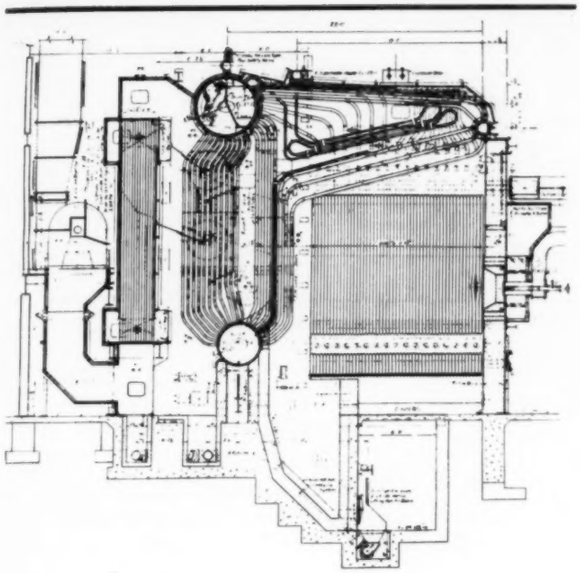


Figure 24—Self-Contained Type Boiler—Wheeling Steel Corporation, Portsmouth, Ohio

The principal advantages of this boiler are quick starting and small space requirements—about one quarter that of the conventional boiler. The weight of boiler and auxiliaries is about one tenth that of the conventional boiler and auxiliaries. Raising the boiler to full steam pressure from a cold start requires about five to eight minutes. A boiler of this design has been in operation for almost a year at the plant of an eastern oil company. Thermal efficiencies, including all auxiliaries but the boiler feed pumps have been 90% to 93% on some installations. Figure 30 shows a typical layout of this equipment.

Another boiler of unusual design is the mercury boiler developed by the General Electric Company in conjunction with their mercury turbine. These units, operating on the binary vapor cycle, have a very high efficiency, producing a kw-hr. for about 9,500 Btu. as compared to 11,000 Btu. for the best steam cycle. Mercury vapor leaves the boiler at about 125 lb. gauge pressure and 958° F. temperature and passes through the turbine, which in some cases has been placed above the boiler. The exhaust mercury vapor is condensed and returned by gravity to the boiler. The mercury-vapor condenser acts as an evaporator, producing steam which is used to operate steam turbines.

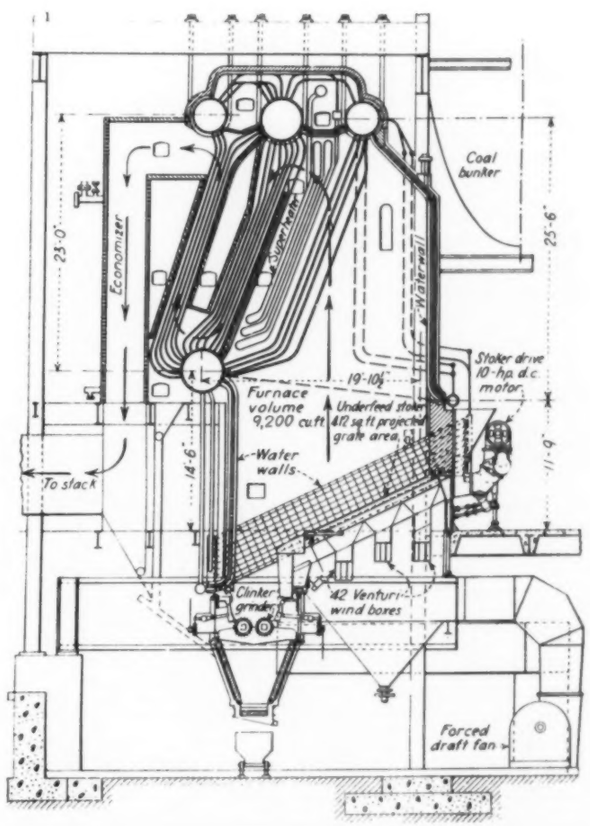
Because of the high cost of mercury, the quantity of liquid in the boiler must be kept at a minimum and the boiler designed to meet this requirement. Figure 31, a cross-section of a boiler drum and boiler tube, shows how the amount of mercury is kept at a minimum by the use of large space-occupying castings installed in the drum and by tubular cores in the boiler tubes. The cores also serve the purpose of aiding the circulation in the porcupine tubes. Trouble has been experienced in keeping solids in the form of oxides out of the mercury. These solids clog up the mercury wall tubes and the very narrow passages between the boiler tubes and the cores causing the tubes to burn. Because of the high first cost and the lesser availability, the units have not yet come into general use; nevertheless, four units are in commercial operation, two of which are of 20,000 kw. capacity.

Figure 32 shows the assembly of a mercury boiler. This boiler has seven mercury drums with the evaporating tubes extending radially from the lower portion somewhat like the quills of a porcupine.

The manufacturer states that two experimental mercury boilers of entirely different design are now being installed. These units will drive 1,000 kw. turbo-generators; the condenser boilers will generate 12,500 lb. of steam at 185 lb. pressure, sufficient for another 900 kw. The boiler at their Pittsfield Plant is of the natural-circulation type with mercury-cooled furnace walls, shown in Figure 33. At their Lynn Plant the boiler is of the forced-circulation type, shown in Figure 34. In this unit all the heating tubes are filled with liquid mercury; the heated mercury is passed through a nozzle into a flash chamber, reducing the pressure 200 lb. The flashed mercury vapor is used to operate the turbine; the liquid mercury returns to the circulating pump. Operating data on these new units are not yet available.

Through the combined efforts of The Babcock and Wilcox Company, General Electric Company and

Figure 25—Stoker-Fired Installation, Pittsburgh Plate Glass Co., Barberton, Ohio



Bailey Meter Company, a complete steam-generating unit has been developed, named the "Steamotive." The object was to make compact, standard-size units of relatively small capacity and high efficiency, automatically operated and complete with all auxiliaries, the units to be self contained and practically portable.

One such unit has been in successful operation for some time. Steam is generated at 1,500 lb. pressure, 900 deg. F. at the rate of 21,000 lb. per hour in an oil-fired boiler with forced water circulation. The auxiliaries are geared together as one unit and consist of a boiler-feed pump of 25,000 lb. per hour capacity at a pressure of 2,000 lb., a blower for 30,000 lb. of air per hour at 60 inches water pressure, a fuel-oil pump and a lubricating-oil pump. Automatic control regulates the fuel supply, air, feed water, pressure and temperature.

On test the heat liberation in the furnace has reached 400,000 Btu. per hour per cubic foot of furnace volume. It is interesting to contrast this liberation with the usual 30,000 to 40,000 Btu. in the ordinary boiler installation or with the possible 80,000 to 90,000 Btu. in the primary furnace of an installation such as that of the Cincinnati Gas and Electric Company.

Two oil-fired units of this type have been constructed for the Union Pacific Railroad Company for driving two 2,500 hp. electric locomotives.

Figure 35 shows an assembly of the "Steamotive." In general units of this sort are not as efficient and economical as larger units but they should be considered where space limitations require a compact installation.

TURBO-GENERATOR

The principal advances in the design of turbo-generators have been: Increase in the size of units, higher speeds, hydrogen cooling, and greater efficiency due in a large measure to the increased pressures and temperatures at which they operate.

Cross-compound turbines, with output capacities as high as 208,000 kw., and tandem-compound units of 165,000 kw. are in operation. The manufacturers can now offer the latter in condensing units for capacities as high as 200,000 kw., 1,800 rpm. and single-cylinder machines as high as 100,000 kw., 1,800 rpm. High pressure, superposed units are usually operated at 3,600 rpm. The largest size on order at this speed is 60,000 kw. and it is understood that the manufacturers are prepared to offer back-pressure units as large as 75,000 kw. at 3,600 rpm. Condensing units of 3,600 rpm. are now available at 25,000 kw., single-cylinder, while 50,000 kw., two-cylinder, 3,600 rpm. machines are in the offing. Steam temperatures have been raised to 900 deg. F.—950 deg. F. by use of special alloys for

Figure 26—Combination Fired Installation—Tangential Firing—Carnegie-Illinois Steel Company

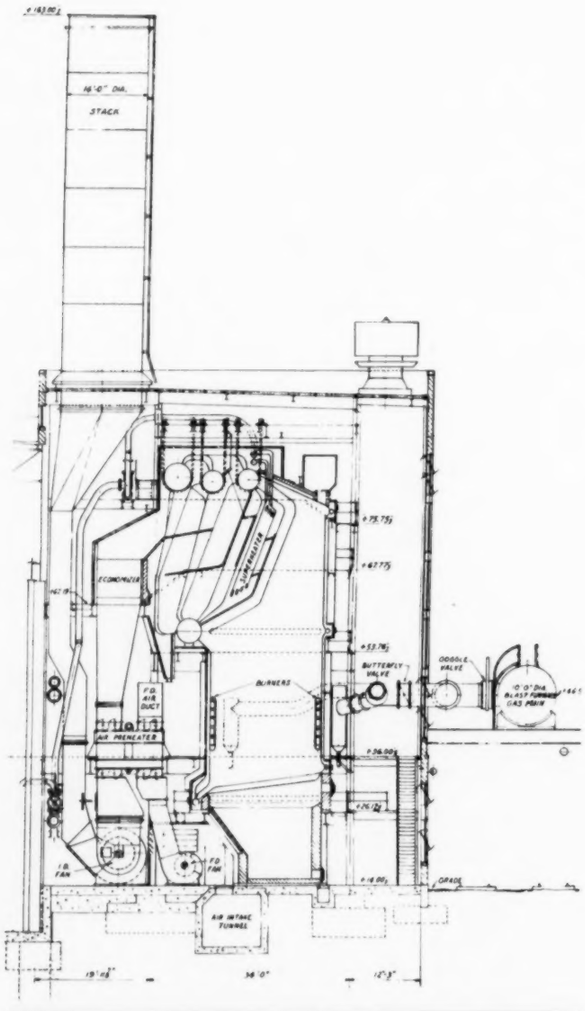
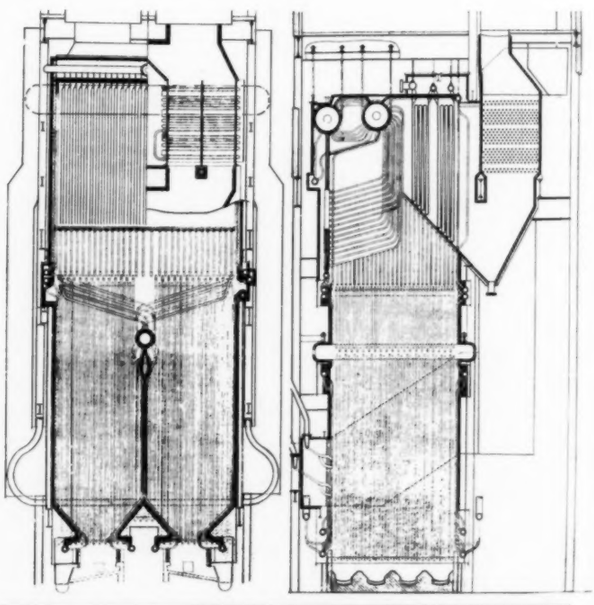


Figure 27—Novel Boiler Design and Special Superheater—Windsor Station



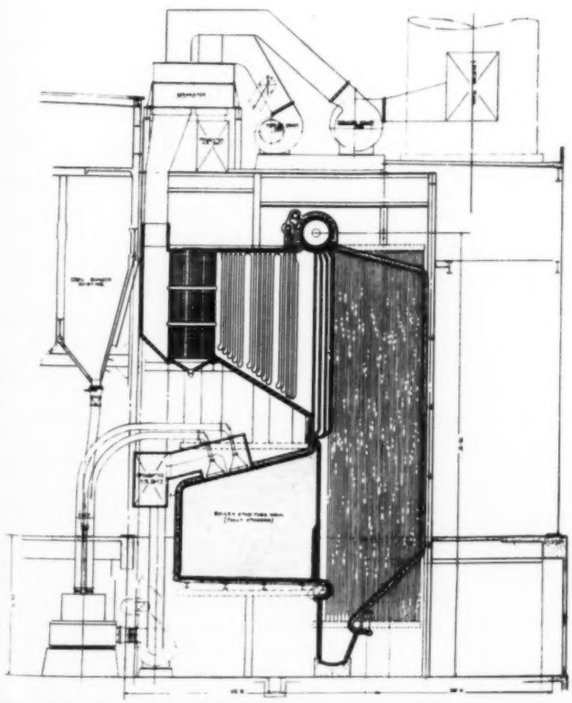
turbine parts coming in contact with high-temperature steam. If reheating between stages is to be avoided, the steam pressures are limited by the allowable temperature to about 1,250 lb. in order not to exceed a safe moisture content in the exhaust steam of about 12%.

The huge quantities of steam involved in the large condensing turbines require low-pressure blades of unusual size. On a 165,000 kw. unit they are 38 inches long and operating at 1,800 rpm. the tip speed is 74,200 fpm. Great credit is due the turbine manufacturers for the development of materials and designs which can withstand the enormous stresses imposed on the blades at these speeds. It is quite general to arrange the low-pressure end in a double-flow manner, thus cutting down the length of the low-pressure blades.

In order to minimize distortion of the shaft from uneven cooling after taking large units off the line, provision is made to rotate the shaft at low speed with a motor-operated turning gear attached to the turbine shaft. This assures even cooling of the rotor and upon restarting permits bringing the unit up to speed in a short time. A 165,000 kw. turbine can be safely started from room temperature and put on the line in sixty minutes.

Special instruments have been developed by the turbine manufacturers for recording expansion, eccentricity and vibration of the turbine shaft and they supply valuable information as to the behaviour of the shaft during the starting period. However, the design of some of them is not yet perfected to such an extent as to make the readings absolutely reliable.

Figure 28—2500-Lb. Pressure Boiler with Closed Wet-Bottom Furnace—Twin Branch Station



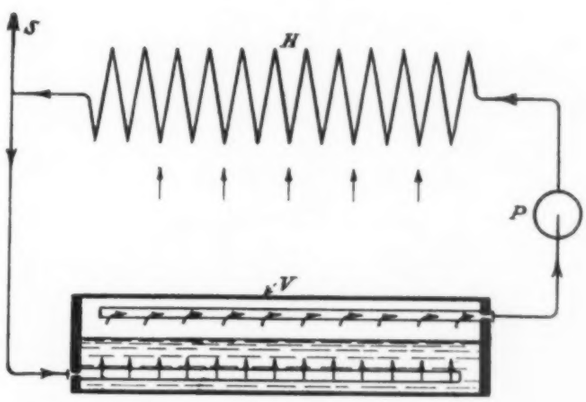
Lubricating and governor control oil for the turbine constitutes a real fire hazard, particularly with present high temperatures. Great care has to be taken that all piping connections are of the highest order, to prevent leaks or breakage. For governor oil, which is under higher pressure, about 100 to 125 lb., a reliable non-inflammable substitute has been used in several cases, but later designs are using regular oil for governor operation, taking particular care that the piping connections are so located that leaks shall not drip on high-temperature surfaces.

Figure 36 shows a typical high-pressure, condensing tandem-compound turbine of 25,000–50,000 kw. capacity. The steam admission is of the multivalve, bar-lifting type.

Superposing high-pressure machines on low-pressure equipment, while not new, has lately found many applications. Power plants which, on account of low pressure and temperature conditions, had been reduced to stand-by service are now being rejuvenated and turned into base-load equipment by the installation of high-pressure superposed units. Experience shows that the 200-400 lb. turbines and auxiliaries installed fifteen to twenty years ago are good for many more years of service, and therefore the installation of high-pressure boilers and a high-pressure topping unit, exhausting into these old turbines, permits bringing a station back to high efficiency with a minimum expenditure of capital, while at the same time increasing the station capacity by the size of the superposed machine.

A superposed unit of unusual design located in Waterside No. 2 Station is shown in Figure 37. Steam is expanded in the high-pressure 49,500 kw. turbine from 1,200 lb., 900 deg. F. to 200 lb. pressure. The exhaust steam is passed into the old station steam header and through existing low-pressure turbines for further expansion. In the plant for which this unit was bought the low-pressure turbines were not arranged for steam extraction, and in order to get steam for feed heating, a 3,500 kw. low-pressure turbine is mounted on the shaft of the superposed unit. This turbine is supplied with part of the 200 lb. exhaust from the superposed

Figure 29—Loeffler Boiler Cycle



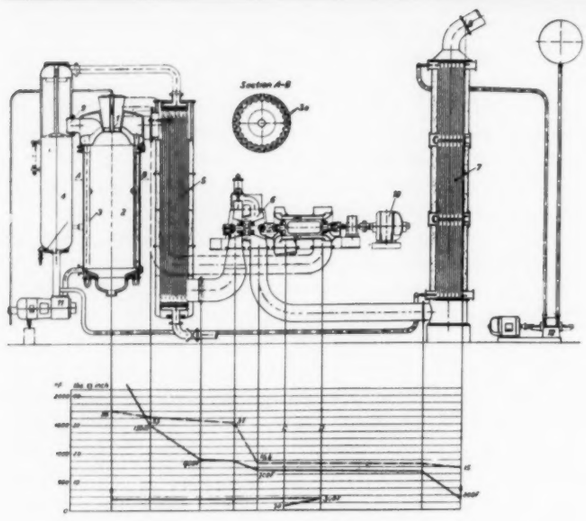


Figure 30—Outline of Velox Boiler

unit, and is arranged for extraction at 60 lb. gauge and for exhausting at 5 lb. gauge. The extracted and the exhaust steam is used for feed heating. The independent governor of this auxiliary turbine maintains the exhaust pressure constant; the power generated is transformed into electrical energy by the main generator.

Of interest to industrial users is the turbine shown in Figure 38. This is a 7,500 kw. condensing turbine, operated with steam at 625 lb. pressure and 725 deg. F. temperature. Steam is extracted at a pressure of 110 lb. for process work, and maintained constant by a governor-operated grid valve placed within the turbine casing.

Figure 39 shows a 6,000 kw. non-condensing turbine with steam extraction at constant pressure. These units have been developed for steam-inlet conditions up to 1,400 lb. pressure, 950 deg. F. total temperature. Exhaust steam conditions are chosen to suit the pressures and temperatures of the process steam required.

The double-wall-cylinder construction for high-pressure turbines shown in Figure 40 is of interest. The space between the walls is subjected to bleeder pressure and so the pressure differential from the inside of the turbine to the jacket is reduced. This permits the use of thin cylinder walls and reduces the stresses in these walls due to uneven heating in starting and in changes of load. The radiation losses from the cylinder are also reduced since the extraction steam in the jacket is at lower temperature. The new topping unit being installed at the Essex Station of Public Service Electric and Gas Company is of this type.

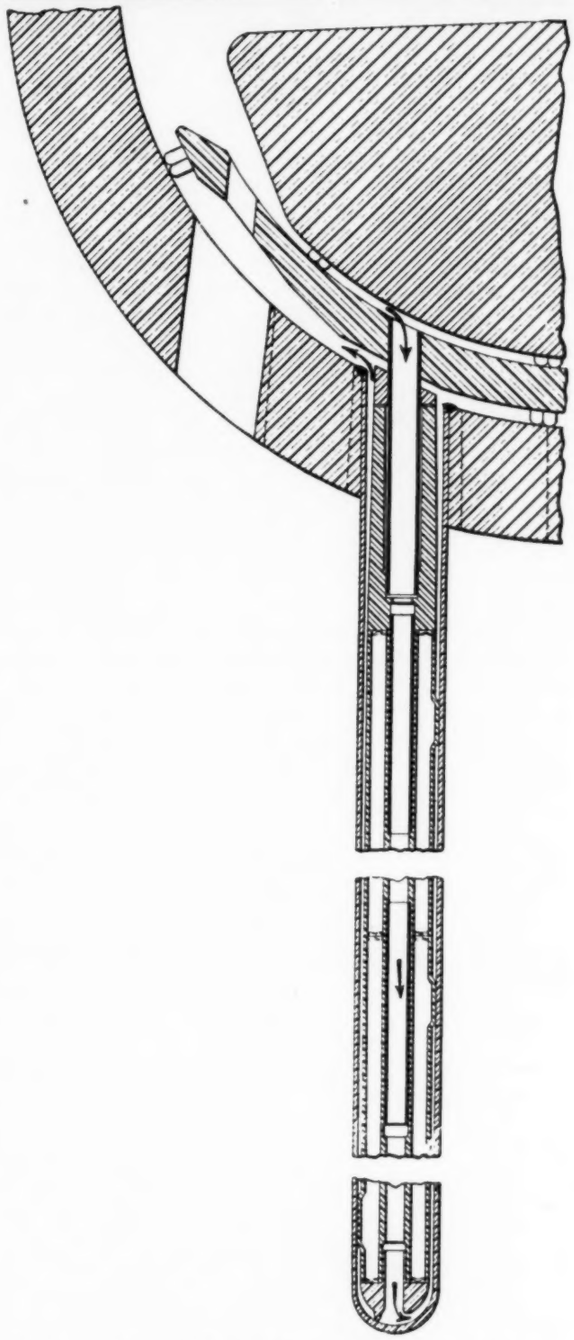


Figure 31—Mercury Boiler Showing Castings for Limiting Quantity of Mercury Used

GENERATOR COOLING

Up to the present time air has been used exclusively as a cooling medium for large generators. In the early stages, the cooling air was passed through the generator without cleaning. Later, the outside air was thoroughly washed by means of water sprays, then dehydrated and passed through the generator. Difficulty was encountered with each of the methods due to deposits in the windings and as the capacity of generators increased this method was supplanted by the closed system wherein the same air is used over and over. Heat is extracted from the air by means of fin-covered tubes through which cooling water flows. Sometimes condensate is used but frequently condensing water serves as the cooling agent. The air is circulated by means of fan blades mounted on each end of the generator rotor. On very large machines external fans are necessary.

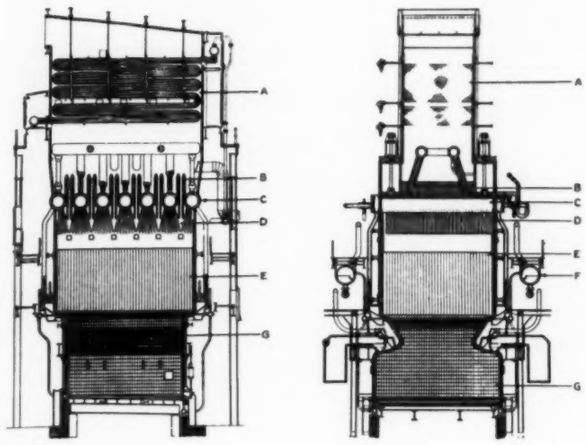


Figure 32—Mercury Boiler Assembly Showing Porcupine Tubes

In an effort to increase output per unit of materials used, engineers have perfected the 3,600 rpm. turbo-generator and on large sizes hydrogen is rapidly replacing air as a cooling medium. Whereas, in 1935, no hydrogen-cooled generators were on order with any manufacturer, many large generators now on order above 25,000 kw. are hydrogen-cooled, and it is quite probable that in the future all generators of a substantial size will be hydrogen-cooled. The first units of this type have just gone into service although much previous experience had been gained from the application of hydrogen to synchronous condensers and frequency converters.

The principal advantages resulting from the use of hydrogen are:

1. Reduced windage losses and less noise, as hydrogen is 1/14 as heavy as air. The increase in generator efficiency may approximate 1½ points.
2. Absolute freedom from dirt and moisture.
3. Higher rate of heat dissipation. Its thermal conductivity is seven times that of air and its specific heat is almost the same. Also the heat-transfer coefficient from surface to gas is ⅓ greater with hydrogen than with air.
4. Increased life of insulation because of the absence of oxygen and moisture in the presence of corona.
5. The complete elimination of the deteriorating effects of corona in the windings considerably increases the possibility of raising the voltage limit of generators. Heretofore the advisability of constructing generators for 22,000 volts has been very doubtful. Some large machines have been built for this voltage but operating difficulties have been experienced. Hydrogen-cooling should aid in the development of satisfactory 22,000 volt machines.

It is of interest to note here that at State Line Station of State Line Generating Company a 22,000 volt machine, which was not completely installed, is being changed over to hydrogen cooling.

The danger of explosion is eliminated by keeping the mixture 95% hydrogen and 5% air, which is safely above the most hazardous mixture, namely 35% hydrogen and 65% air. The latter combination, if exploded, will develop pressures of 80 lb. to 90 lb. per sq. in. and for this reason all generator casings are designed to withstand these pressures.

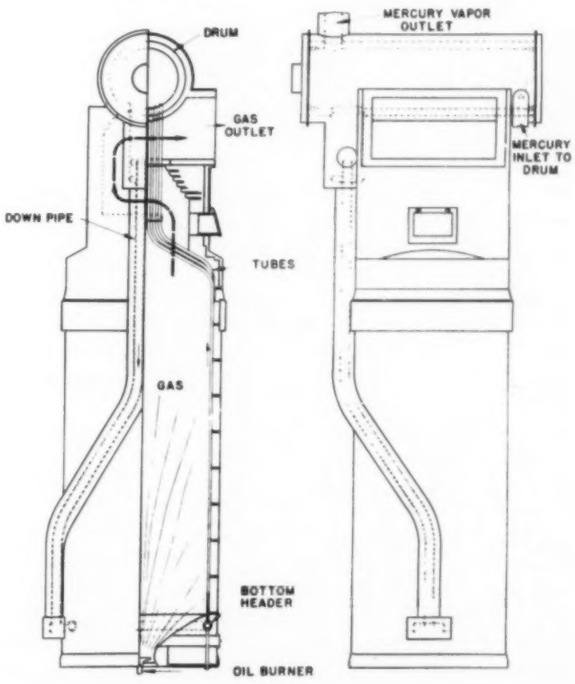
Normally the hydrogen pressure is under ½ lb. per sq. in. but by raising it to 15 lb. the generator capacity can be increased approximately 15%. On the other hand, if all hydrogen is lost the unit can be operated on air at about 70% full rating.

A typical hydrogen-cooled generator is shown in Figure 41.

Integral fan blades mounted on each end of the generator shaft blow the hydrogen gas into the air gaps and then radially to all parts of the unit. The gas coolers are usually mounted inside the generator housing and at the top for accessibility and to permit cleaning without removal of the hydrogen gas. Suitable drain troughs and alarms protect the generator from water leaks.

The shaft seals are the only feature on hydrogen-cooled generators which have been developed without previous experience on synchronous condensers. The main unit lubricating oil is pumped through annular grooves usually integral with the shaft bearings. This oil is collected in a tank for removal of hydrogen picked up in the seals. When the generator is out of service, this oil pumping and reclaiming system continues in operation.

Figure 33—Natural Circulation Type of Mercury Boiler—General Electric Company Pittsfield Plant



The automatic control system maintains gas pressure just above atmospheric value so that leakage will be always outward. Likewise gas density meters and alarms provide additional safeguards.

GENERATOR ROTORS

During recent years, considerable improvement has taken place in the construction of rotors for 3,600 rpm. machines. The method of cooling the rotor has been improved and better materials have been developed to enable it to withstand higher mechanical stresses. Although hydrogen-cooling has made possible the use of smaller-diameter rotors for given outputs, the stresses due to centrifugal forces are nevertheless very high for the largest machines. Aluminum is therefore being used instead of copper for the rotor windings, by some manufacturers. This type of construction may eventually become necessary for all very large machines.

During recent years, considerable improvement has been made in the insulation of armature coils and with better methods of protecting generator windings from excessive transient voltages, generators installed in the future should be almost entirely free from the hazards of voltage breakdown.

CONDENSING EQUIPMENT

The advance in condenser equipment consists principally in refinement of design. Condensers are made with one, two or three passes of circulating water, the number of passes depending on the quantity of circulating water available. When the supply is abundant, the single-pass condenser will generally work out to the best advantage. Pumping cost will be only slightly higher with single-pass construction because the quantity of cooling water is larger but operating and initial costs of condensing equipment will be less.

Feed heating by extracted steam and improvement in tube spacing and steam laning have substantially reduced the cooling surface required per kw. output. This is illustrated by the condensers at Conners Creek Plant of the Detroit Edison Company. These condensers were installed about twenty years ago with 32,500 sq. ft. of surface for 20,000 kw. non-bleeding turbo-generators. In reconstruction with higher throttle pressure and temperature the capacity of the units was increased to 30,000 kw. and about 28% of the throttle steam was bled to feed heaters. A large number of tubes were removed from the condenser to insure better steam laning, higher water velocity, better heat transfer and reduction of under-cooling losses. The cooling surface was reduced to 27,000 sq. ft., or .9 sq. ft. per kw. as against 1.625 sq. ft. per kw. in the original installation. Similarly the condensers for 45,000 kw. units were changed for use with 60,000 kw. turbo-generators and the tube surface reduced from 1.35 sq. ft. to .667 sq. ft. per kw. The tube spacing is now generally arranged in such a way that condensate reaching the hotwell is at the boiling point, insuring deaerated water and preventing heat losses from sub-cooled water, thus reducing losses to the condenser circulating water. This construction also frequently makes unnecessary the installation of deaerating heaters.

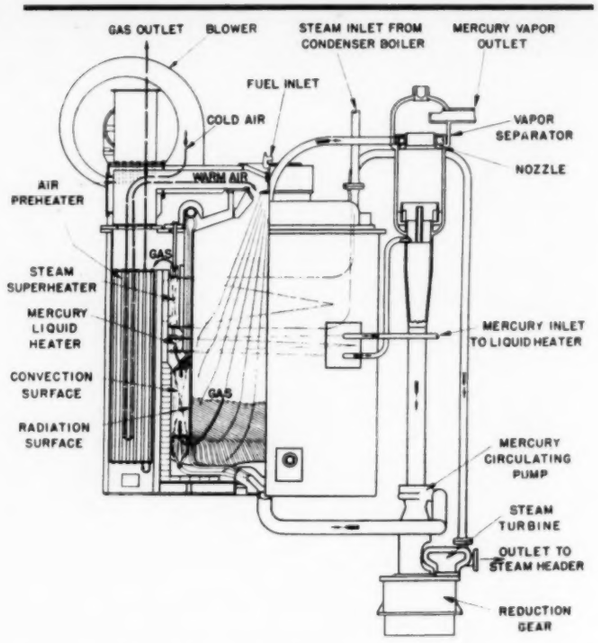
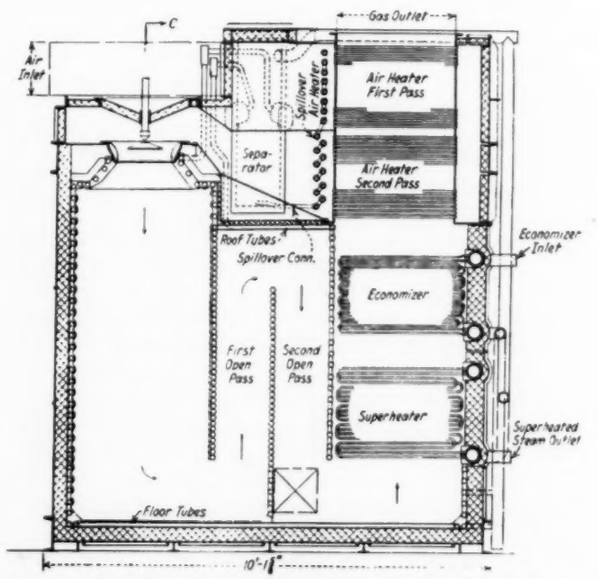


Figure 34—Forced Circulation Type of Mercury Boiler—General Electric Company Lynn Works

Fear of internal corrosion and air leaks has been the cause of the universal use of cast iron condenser shells. However, since welding has been accepted by power plant engineers, the welded, steelplate shell has found more favor. As turbine-exhaust casings are also being made of plate steel, the connection between turbine and condenser may be welded, eliminating the bolted joint.

Figure 35—The "Steamotive"—A Recent Boiler Development



Muntz and Admiralty metal tubes are used almost universally for condensers located on fresh water. Where the cooling water is salt or brackish, or contaminated with sewage or mill waste, the problem of finding suitable material for tubing becomes quite involved. Pure copper, arsenical copper, aluminum brass, red brass and other alloys are used, each having its particular advantage depending on the nature of the water available. No general rule can be laid down for choosing the proper alloy and only experience with all kinds of experimental tubes used under actual operating conditions will furnish the final answer as to the most economical material.

Modern operating conditions require that condenser leakage be kept to a minimum. Corset-lace packing of tubes used almost universally twenty years ago has been largely replaced with metallic packing and now in a great many cases tubes are being expanded into the tube sheets. Where both ends of the tubes are rolled into the tube sheet expansion can be taken care of in several ways: first, by the installation of an expansion joint in the shell; second, by rolling the tubes while heating the condenser shell and tubes to about 200 deg. with exhaust steam in the condenser; third, by bowing the tubes between the tube sheets.

Improvement in water-box design for elimination of entrained air and for proper entrance of water into the tubes is highly desirable. Tube failures caused by eddy currents and entrained air at the tube entrance are still frequent.

In locations where condensing water is particularly contaminated by sewage or other materials liable to cause gas when the circulating water is subject to a slight vacuum, it is highly desirable that the inlet water-boxes be vented. This can very readily be done by making a connection from the inlet water-box to the discharge side of the condenser using the condenser drop leg to produce a vacuum for removal of gases.

Many plants experience trouble with a slime deposit and algae on the inside of the condenser tubes which interfere with the heat transfer. Their removal by mechanical means, such as rubber plugs and brushes, is quite costly. Chlorinating the cooling water before it enters the tubes has proved beneficial in nearly every case where it has been done. Chlorine gas is usually dissolved in water and the solution is forced into the condenser cooling water, preferably as near the circulating pumps as possible. The solution is made of sufficient chlorine content to show residual chlorine in the cooling water after it has passed through the condenser. The solution is admitted at intervals, the frequency and the duration of time at which the solution is applied being determined by trial when the equipment is first installed and adjusted at times to meet conditions. Automatic operation of the chlorine feed can be had by the installation of suitable time clocks.

While the chlorine solution is very corrosive and is conveyed through rubber-lined pipe, after the solution has been properly mixed with the cooling water, no corrosion trouble has been experienced.

Where condensers are subject to fouling, the use of divided water-boxes permits the cleaning of the tubes and tube sheets for half the condenser at a time without shutting down the equipment. This cleaning is generally done when the unit carries low load and proper vacuum can be maintained with half the condenser surface. In situations where frequent fouling of condensers approaches the danger point, some relief can be secured by putting high-pressure washing jets in the inlet water-box. These can be used for cleaning the tube surface while the condenser is in operation.

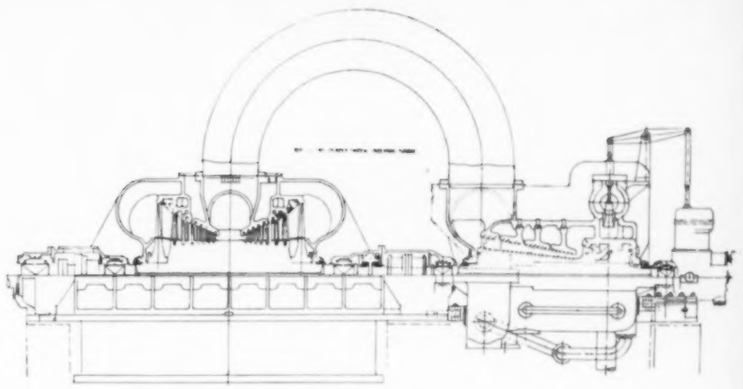
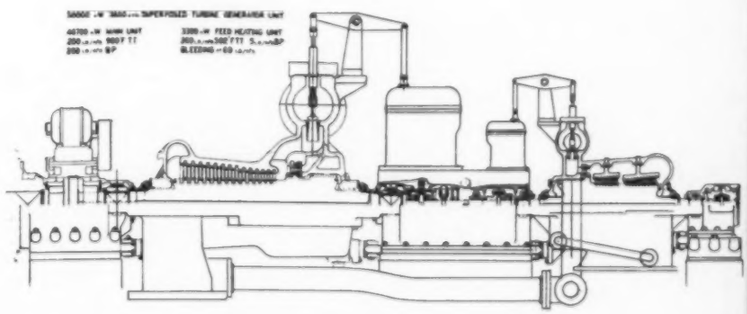


Figure 36—High-Pressure, Condensing, Tandem-Compound Turbine

To save floor space a few of the larger stations have in recent years installed circulating-water pumps of vertical design, using propeller-type runners. These pumps have given satisfactory service and have proved efficient. Since they are submerged in the circulating water no priming is necessary to start them.

Traveling screens are now in almost universal use and are fabricated with heavier baskets than formerly, to withstand higher level differentials caused by fouling when screens are not revolving. Several installations have been provided with recorders and alarms operated by the differential in water level on the two sides of the traveling screen.

Figure 37—Superposed Turbine Unit—Waterside No. 2 Station



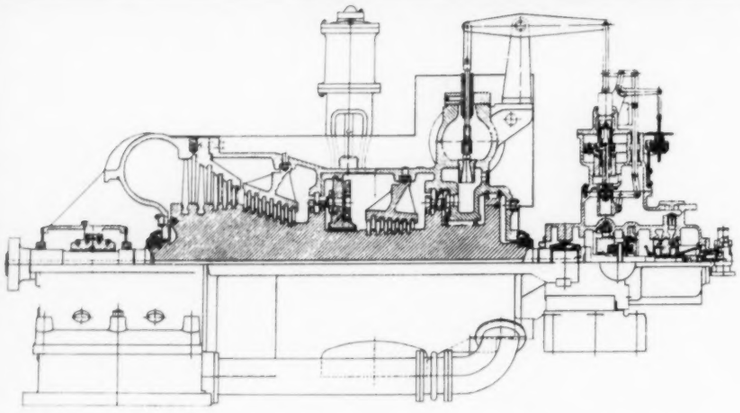


Figure 38—Single-Extraction Turbine—Condensing

FEED HEATING

Unless steam-driven auxiliaries are highly desirable for a specific reason, feed-water in the modern plant is heated with steam bled from the turbine. This permits the maximum of energy to be extracted from the steam before it is used for feed heating. The heating is done progressively from condensate temperature to boiler feed temperature in steps of about 60 to 70 deg. F. each. The more heating stages used, the better the thermal efficiency of the plant. However, the gain in thermal efficiency must be balanced against the cost to obtain that efficiency. It is for this reason that we find new plants being designed with three, four, or more stages of feed heating, the selection depending on careful calculations in regard to efficiencies and costs.

Since extraction heating has become prevalent, closed feed-water heaters have been used nearly exclusively and have given very satisfactory service. The principal complaints have probably been the occasional cracking of the heat-transfer tubes, corrosion due to air entrained with the bled steam, and leakage at the joints where the tubes are rolled in the tube sheets.

Condensed, bled steam from the closed heaters is either trapped and cascaded to lower-pressure heaters or pumped into the feed line ahead of the heater. Cascading makes a simpler layout, easier to maintain, but pumping the condensate shows higher thermal efficiency. The feed-water outlet temperature at each heater usually averages about three degrees F. lower than the saturated-steam temperature, although by taking advantage of the superheat in the steam, the outlet temperature of the last heater can be made to equal the saturated-steam temperature.

Within the present decade a new design of heater for extraction feed heating has been marketed, wherein the steam is brought in direct contact with the feed water, raising the water temperature to saturated steam temperature. This slightly higher feed temperature (about three degrees F. for every stage of heating) means a considerable fuel saving annually. However, the higher first cost and the higher pumping cost may offset this saving in some instances.

In this design the water is sprayed in each heater to get direct contact with the steam and to bring it to the saturated-steam temperature. Each heater requires a pump to remove the heated water from the heater and discharge it to next heater. To secure proper regulation all of the heater pumps should be driven by a single motor or turbine. This extra pumping equipment is thought to be objectionable by some operators. The vents are passed through vent condensers before being cascaded back to the lower-pressure heaters and are finally discharged into the condenser.

These heaters have given good results although trouble has been experienced with water hammer, and with cavitation in the removal pumps, requiring frequent replacement of impellers. Much of this trouble is being or has been corrected by keeping the impeller submerged. Comparative heat-flow diagrams are shown in Figure 42 for contact and closed heaters.

FEED-WATER TREATMENT

Treating of feed-water is still a highly specialized art and should not be contemplated by the operating engineer except on advice from a chemist who makes feed-water treatment his life's work.

Where all condensate from a high-pressure installation is returned to the boiler, the small percentage of make-up is generally supplied by an evaporator and if any addition of chemicals is necessary they can be supplied to the boiler feed. In many cases it will be found desirable to treat the evaporator supply also. In case the feed-water make-up is extensive, the evaporator cost and the loss of potential energy in the evaporator becomes of such importance that chemical treatment of raw make-up is desirable. With the advance in the art of feed-water treatment, there should be no hesitancy in using large percentages of chemically-treated raw water in high-pressure boilers providing the application is under the supervision of a capable feed-water chemist and the proper treating equipment is installed. In such cases the rating at which the boilers operate will have to be carefully considered.

The hot-process softener is principally used for treating large quantities of raw make-up water. The water is treated with lime, which removes practically all calcium and magnesium carbonates, and with soda ash, to convert the sulphates and chlorides of calcium and magnesium to the sulphates and chlorides of sodium. These sodium salts are non-scaling. Phosphate treatment of the water in the boiler is usually necessary to prevent scale deposit and to facilitate maintaining a suitable sulphate-alkalinity ratio.

Inasmuch as the hot-process softener does not eliminate all the salts from the water entering the boiler it becomes necessary to keep the concentration of the salts in the boilers within bounds by some supplementary method. By using a continuous blow-down system, the concentration can be kept nearly constant at the most desirable point and the heat in the blow-down water can be recovered by means of flash tanks and heat exchangers.

Hot-process softeners are now being provided with a deaerating section in the heaters in order to eliminate the non-condensible gases, so that separate deaerating heaters can be omitted.

PIPING

With the rapid advance made in the art of welding, power plant designers have not hesitated to use welded joints in pipe lines, even for the most severe service. Experience has shown that welded joints, made by qualified workmen under adequate supervision, are entirely dependable and eliminate all trouble experienced with flanged joints, such as leaks due to uneven expansion and change in physical characteristics of bolt material due to repeated stresses or to being stressed above the elastic limit of the material.

Steel valves are being welded in high-pressure lines and State boiler inspectors in some instances have permitted the welding of valves to the pressure parts of the boiler without X-raying, although that is not yet permitted by the A. S. M. E. Boiler Code. In many cases the entire steam line between the superheater and the turbine throttle is being welded with no flanged joints at all in the pipe line.

Electric fusion-welding is generally preferred for welding of power-plant piping, although excellent results have been obtained with oxyacetylene welding, especially if the weld is made by applying the weld material in several layers as is done in electric welding. Applying the additional layers of weld material seems to have a refining influence on the preceding layers of weld metal and tests show that the ductility of the weld is greatly improved.

Electric welding is generally done with coated electrodes, in order to exclude the air from the liquid metal in the weld. The weld metal is laid on in layers about ⅛ inch thick, which are wire-brushed or chipped clean before succeeding layers are applied. Butt welding, without straps, has been found to give as satisfactory a job as any of the reinforced welded joint designs which were common some years ago.

Present-day trends towards higher temperatures and pressures have necessitated special attention for pipe lines and valves with their requirements for new types of material, special alloys, etc. Although several alloys are suitable for this service, in the past they have not been commercially available as seamless pipe and in the sizes required for power plant construction. Through the combined efforts of the manufacturers and the consumers, progress has been made, and it is now possible to obtain seamless carbon molybdenum pipe in sizes up to fourteen inches outside diameter. It was mutually agreed to concentrate on the manufacture and use of carbon molybdenum alloy because in fabrication, this material appears to give the least trouble of all the ferrous alloys suitable for high-temperature service; also manufacturing is simplified by the concentration on only one alloy. Figure 43 shows that the creep strength of this alloy is more than twice as high as carbon steel at 950 deg. F. and approximately as good as the higher chrome alloys. This means that wall thickness of carbon molybdenum need be only ½ the thickness of carbon-steel pipe at 950 deg. F.

Cast-steel valves can be obtained in almost any alloy desired but carbon molybdenum has an advantage in that the use of similar alloys in the pipe and the valves simplifies the welding, particularly field welding.

It is considered good policy that all welders employed to weld high-pressure piping be tested and qualified by a reliable agency such as one of the boiler inspection and insurance companies and that the same agency inspect all shop and field welding. In this way, good workmanship is obtained, one of the most important items of a successful welding job.

Whether or not completed welds have dangerous internal stresses in the material at the weld has not yet been definitely proved. Recent tests indicate that internal stresses of serious proportions exist in non-stress-relieved welds. It is, therefore, still considered good practice to relieve such stresses as far as possible by slowly heating the welded joint to a temperature between 1,150 and 1,200 deg. F. and thereafter cooling slowly. This stress relieving is considered very important in alloy-steel piping and is also applied to fabricated piping in order to relieve stresses set up in the fabrication of pipe bends.

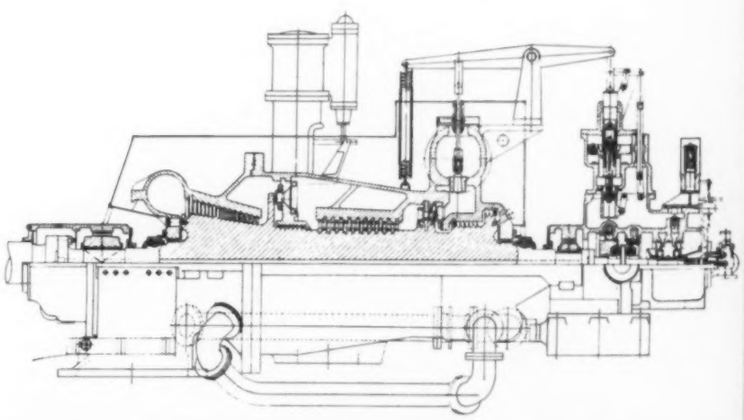
Materials which are subject to air hardening, such as alloy steels and carbon steel with a carbon content above .30%, should be preheated before welding is started; the temperature of the preheat depends somewhat on the characteristics of the metal, but in general 400 deg. F. to 600 deg. F. is found to be satisfactory.

Because of better temperature control it is desirable that both stress relieving and preheating be done electrically. This can be readily accomplished in several ways and the temperature of the pipe taken by thermocouples.

In line with the desire of power-plant designers to eliminate bolted joints, valve manufacturers are now experimenting with designs for holding the valve bonnet to the body by means of special joints, either eliminating bolts in tension or reducing the stresses on the bolts which hold the gasket. This work is still in the development stage, but is a step in the right direction. Bonnet joints as well as line joints have been troublesome and improvements will be welcome.

Valve discs and seats for high-pressure, high-temperature valves are generally constructed of stainless steel; if the temperature is above 850 deg. F., the stainless steel is usually faced with Stellite, a cobalt

Figure 39—Single-Extraction Turbine—Non-Condensing



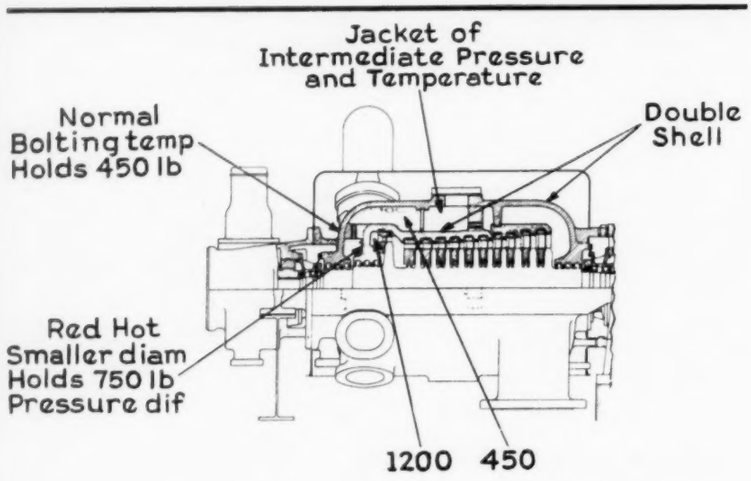


Figure 40—Double Wall Construction—High Pressure Turbine Cylinders

alloy, which is fused on. For temperatures below 850 deg. F. stainless-steel or copper-nickel alloy facings can still be used satisfactorily. In order to eliminate leakage past the threads of screwed-in seats, it is now quite customary to weld the seat to the valve body.

In power plants with rapidly fluctuating loads electrically-operated relief valves are used in order to reduce steam losses at the popping pressures. One of these valves is usually installed on the steam header in addition to the required number of boiler, pop-safety valves; it is operated by a solenoid, energized when electric contact is made by a pressure-operated Bourdon tube. The setting can be made very accurate and is slightly below the popping pressure of the boiler safety valves. The valve reseats when the pressure falls about one per cent below the relieving pressure, saving the steam usually lost in the blow-back, which with ordinary pop-safety valves amounts to three or four per cent.

PRESSURE REDUCING AND DESUPERHEATING

Many high-pressure power plants are being built as additions to existing plants operating at lower pressures. In order to use steam from the new high-pressure boilers for the existing low-pressure equipment, the pressure and temperature of the steam has to be reduced and controlled within close limits. Also where the exhaust from a high-pressure turbine is used for operating existing low-pressure turbo-generators, it is important that the steam supply to the old units be not interrupted in case the high-pressure machine kicks out. It is, therefore, essential that live steam be supplied through the reducing valve before the low-pressure turbo-generator stalls. The ordinary method of controlling the pressure-regulating valve by pressure on the low side of valve is considered too slow to give this protection; it is therefore assisted by auxiliary control equipment which will start to open the valve before the pressure has dropped. This control equipment can get its signal from an impulse off the hydraulic governor of the high-pressure turbines or from a "load anticipator" which will put the reducing valve into action when the generator load drops rapidly from any cause whatever.

Not only the pressure but also the temperature of the steam must be controlled quickly to prevent expansion troubles in the old turbine. The controls are, therefore, arranged to reduce the temperature of the steam as well as the pressure. Desuperheating equipment, or rather steam temperature control equipment, used in power plants usually operates on the plan of introducing water into the steam, although surface-type heat exchangers have been used. Three methods of mixing steam and water are used:

1. Spray nozzles for spraying water as a fine mist into the steam main.
2. Basket type, where the water is made to trickle over metal parts contained in a perforated basket, while the steam passes through at right angles to the flow of water.
3. The constant-water-level type, where part of the high-temperature steam is completely desuperheated by the water and then mixed with the remainder of steam which is not tempered, the final temperature being maintained by properly proportioning the desuperheated and the untempered steam flows.

The above three types have worked out satisfactorily, wherever suitable control equipment was provided to maintain the proper mixtures.

Condensate should be used when available for temperature reduction to prevent solids from being introduced into the steam. Where it is necessary to use water containing considerable amount of solids, some provision should be made to prevent these solids reaching the turbine.

The control equipment for pressure reduction and temperature regulation is usually of the same order as that used for combustion control.

FANS

Since the advent of water-cooled furnace walls, steam output per foot-width of boiler furnace has steadily increased. As a consequence draft loss through the boiler and economizer has also become greater. High steam temperatures have called for larger superheaters, which, when crowded into the narrow boiler width, further increase draft losses. The draft losses in a modern boiler, with its high steam temperature and its heat traps, call for induced-draft fans of high suction pressure. A recent boiler design required induced-draft fans with a suction of 23 inches of water; there were two fans per boiler, each to be driven by a 1,000 hp. motor.

Selection of fan drives and control of fan output becomes more important with increasing requirements for auxiliary power; dependability, efficiency, space requirements, simplicity of control and demand on the station electric power output must receive due consideration.

For meeting the varying fan output required at different boiler loads, the air or gas flow may be controlled by dampers on fans operated at constant speed

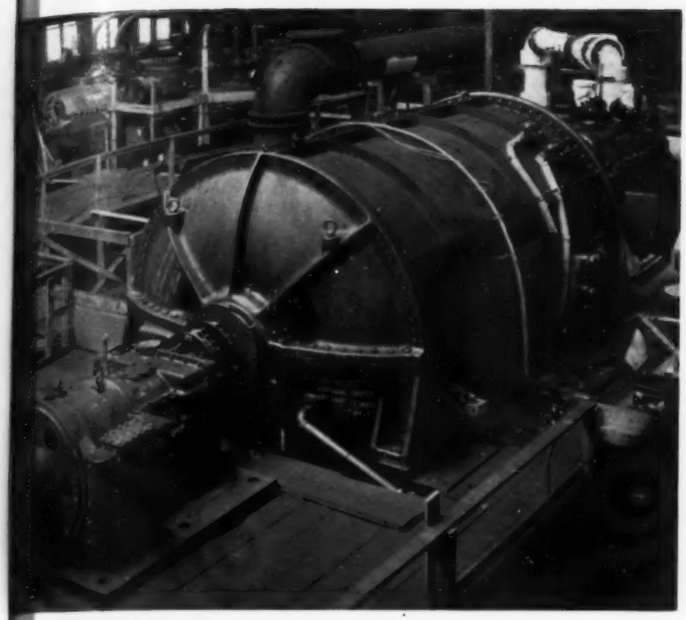


Figure 41—Typical Hydrogen-Cooled Generator

or by variable-speed drive. For small fans damper control, including vane control, is generally satisfactory and economical, but for larger fans, the power costs usually warrant the use of variable-speed drives. A modern development in variable-speed fan drive is the hydraulic coupling, which permits the fan to be operated at variable speeds with a constant-speed motor. The coupling consists of two halves not connected mechanically, but so arranged that oil introduced in the coupling will cause the half coupling attached to the fan to be pulled along by the half coupling attached to the motor. The speed with which the fan is pulled along can be controlled over a range of 20% to 98% of the motor speed by varying the quantity of oil in the coupling which in turn can be easily regulated by the combustion control equipment. Several of these couplings are in successful operation in this country some of which operate at 700 hp., 900 rpm. Experience has shown that the efficiency is numerically about the same as the percentage of speed and since there are an infinite number of speeds, the efficiency, over its speed range, is somewhat better than that of a slip ring motor drive. Also first cost and space requirements are often in favor of its selection.

When the boiler load changes, the speed of the forced-draft fan changes about in proportion to the change of speed of the induced-draft fan. Therefore, if these fans are selected to operate at the same speed, it would be possible to drive the two fans by one variable-speed drive and get very nearly the desired output of each fan. By controlling the speed to a point somewhat above that required for correct combustion conditions, the excess output can be reduced by dampers to desired combustion requirements.

A combination of forced and induced-draft fan, built as a unit, with one variable-speed drive saves considerable floor space and reduces the first cost of the unit and of the wiring and piping connections. The operating cost will be somewhat higher than for independent drives on account of the extra power required in dampering. This development is now offered by some manufacturers.

For industrial installations fans are often driven by steam turbines. The greater dependability of steam-driven equipment still appeals to those operators who do not have available a supply of electric current from different sources as in the case of large utilities. The increased heat consumption of the steam-driven equipment is of secondary importance in these installations.

STEAM-DRIVEN AUXILIARIES

With the introduction of superposed units, many utilities have found it necessary to install steam drives for some of their auxiliaries in order to get low-pressure steam for feed heating where existing turbines were not arranged for extractions. Auxiliaries such as boiler feed pumps require such a large amount of power that the turbines may be of the extraction type to supply steam for feed heating at more than one pressure. Some of these auxiliaries are of such size, 2,000 hp. not being unusual, that their power demand on the switchboard is of considerable magnitude and the substitution of steam for electric drive therefore increases the power available for outside demands. Further, on account of the large size of the auxiliaries, the turbine drives are very efficient and when operated on the exhaust of the superposed unit their efficiency is nearly as good as that of the main turbines.

BOILER-FEED PUMPS

Developments in boiler-feed pumps have been principally along the lines of perfecting designs for high pressure. Boiler-feed pressures of 1,000 lb. and upward and temperatures of 400-500 deg. F. necessitate great care in balancing the rotor hydraulically and also in preventing leaks and distortion. To produce the high pressures motor-driven pumps are usually operated at 3,600 rpm. and turbine-driven pumps equally high. The high speeds and temperatures require that bearings be supplied with forced lubrication and oil coolers.

Forged steel casings, vertically split, are used in some installations, to overcome troubles with leaky castings and leaky horizontal joints. Shaft sleeves of stainless steel have given excellent service. To keep stuffing boxes tight is still an important problem, particularly if feed-water temperatures vary; special labyrinth sleeves and leak-offs are used at the high pressure end of the pump to break down the pressure before it reaches the stuffing box.

WATER COLUMNS AND GAUGE GLASSES

Water columns for high-pressure service are generally made of wrought steel and have not given much trouble. Gauge glasses are mostly of the box type with flat glasses. Where these glasses are solidly clamped

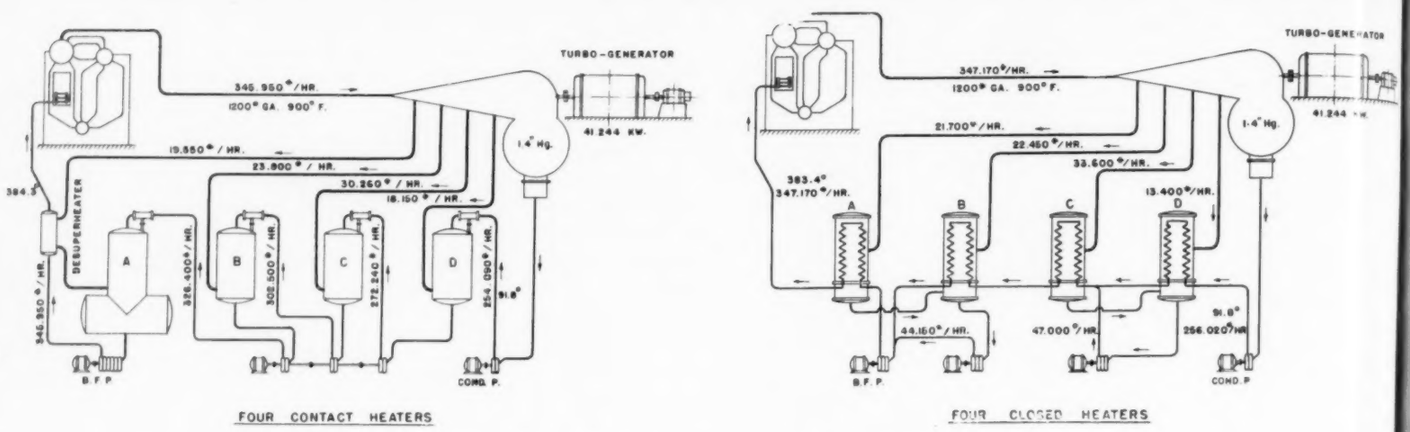


Figure 42—Heat Cycles—Contact and Closed Heaters

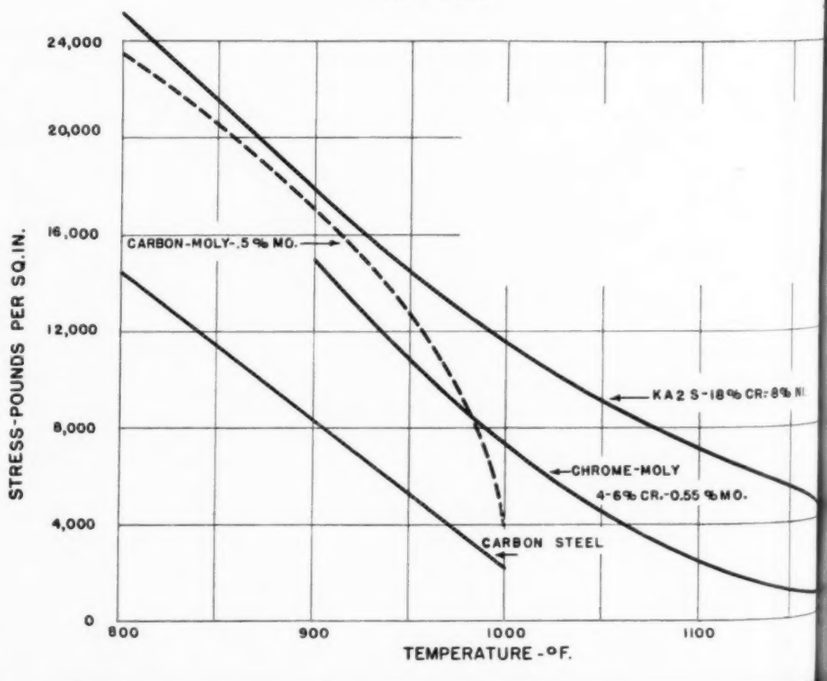
trouble has been experienced with shattering of the glass when exposed to boiler-water temperature. Loose fitted glasses, free to expand, have stood up better.

In the early days considerable difficulty was caused by the condensing steam at the top of the water glass dropping down over the glass and causing serious corrosion. This has been overcome by placing sheet mica between the glass and the water. Mica however, will cloud in a short time and must either be replaced frequently or the clouded inside layer must be peeled off to return better visibility. An interesting development is the bi-color gauge and illuminator which shows the steam space of the gauge glass in red and the water space in green. This design is quite an improvement on the visability of the water level.

CONCLUSION

In the foregoing we have attempted to outline trends in Utility power developments. With the growth of loads in industrial plants, particularly in the Steel Industry, there are many improvements developed by the Utilities which can be adapted and made useful to the steel companies. The question of pressures and temperatures, and of sizes of units, must in all cases be carefully considered for each plant, due consideration being given to installation costs, reliability of service and to the requirements of each individual plant particularly as to the utilization of by-product fuels. While we would not expect that the Steel Industry would find it advisable at the present time to make installations at the extreme pressures and temperatures outlined above, as the use of these pressures and temperatures becomes more and more general and their reliability is proved, the natural tendency of the Industry is going to be towards installations in the future of larger units with increased pressures and temperatures.

Figure 43—Comparison of Creep Strengths—Plain Carbon and Alloy Steels



DISCUSSION

PRESENTED BY

E. R. KAUFMAN, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

F. C. NORTON, Special Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio

E. R. KAUFFMAN: Mr. Clarke's paper on "Steam Power Developments" covers a broad subject in a masterful manner. It is only by elaborating on the major problems of turbine design from a manufacturer's viewpoint, that we can hope to offer any worthy contribution to the discussion.

In connection with the increase in capacity of 3600 rpm. units, our present limit of generator capacity is 60,000 kw. at 90% power factor. An extension beyond this point will not be made until operating data on generators now in operation or under construction, the largest of which is 50,000 kw. at 80% power factor, have been obtained.

In the condensing type of turbine, the limiting capacity is determined by the annular area of the last row of blades. We have designed a 50,000 kw. unit, which is capable of carrying a maximum load of 62,500 kw. for steam conditions of 820 lbs./in^{2}g., 825°F. total temperature and 29″ vacuum. This turbine consists of a single flow high pressure element in tandem with a double flow low pressure element. For higher inlet steam conditions or lower vacua, the rating can be increased and, under favorable conditions, can approach the 75,000 kw. figure given by Mr. Clarke. For unfavorable steam inlet and exhaust conditions, the rating should be reduced below 50,000 kw. unless three or four sets of exhaust blading are utilized. To obtain this additional exhaust blade area will, of course, necessitate the use of a three-cylinder tandem unit.

For non-condensing units, such as the superposed turbine applications, the maximum capacity is limited by the generator only.

As pointed out by Mr. Clarke, the advance in steam pressures and temperatures could not have been accomplished without the development of new materials, particularly alloy steels. In order to utilize the advantages of these alloys to their fullest extent, it has been necessary to carry out extensive studies and tests on the phenomenon of creep. The following are the major advances in this field during the last five years:

1. An increased understanding of the laws that relate creep rates with stress and time, through which serious dimensional changes may be avoided.
2. Reliable long-time creep tests for many of the important materials, which enable the designer to make a relative evaluation of the different materials available.
3. Improved theoretical means for applying the test information to actual design problems.
4. A better understanding of the phenomena of embrittling at higher temperatures, whereby materials susceptible to this influence have been weeded out.

The practical solution of the creep problem takes the form of an intelligent choice of the best material available for each application, coupled with an intelligent interpretation of available test results whereby these materials are used to the fullest advantage.

The problem of creep is of importance in three major details: (a) cylinder shell; (b) cylinder bolting; (c) rotor body. It has not so far been of dominating influence on the choice of materials for blading, although the blade material in general use happens to have good creep qualities. In each one of these major details, the advance of the operating temperature has been fortified by the introduction of a new material with higher creep strength.

In the case of cylinder materials, satisfactory extensive operating experience was available in 1935 for ordinary cast steel (0.35 C, 0.6 Mn, 0.35 Si) at 850°F. maximum steam temperature. Laboratory tests upon carbon-molybdenum steel (0.35 C, 0.6 Mn, 0.35 Si, 0.4 Mo) have demonstrated that its creep properties at 950°F. are comparable with those of ordinary cast steel at 850°F. In the advance of the steam temperature from 850 to 950°F. therefore, very little change in basic design stresses are made.

In the class of bolting materials, satisfactory experience had been obtained at 850°F. with the low-carbon, chromium (0.1 C, 12 Cr) steel. The 950°F. designs are usually carried out with bolts of chromium-molybdenum steels (0.35 C, 0.75 Mn, 0.9 Cr, 0.5 Mo) through which the creep strength has been advanced to permit the use of approximately the same design stresses as those used earlier at 850°F.

For the rotors, the Cr, Ni, Mo steels were used in the 850°F. designs for reasons other than creep. In the solid rotors, for the high-pressure ends of modern machines, the creep problem is not of dominating importance, and this material remains satisfactory at 950°F. as well.

The advance of creep strength of the rotor materials has accentuated the problem of dimensional stability. In a few instances rotor forgings have distorted at higher temperatures to such an extent as to render operation impossible. The conditions are corrected by annealing at 1100-1200°F. and it would seem, therefore, that internal stresses are responsible for the trouble. The elastic behavior at lower stresses suggests a mechanism similar to a bimetallic strip, however, and there the theory of internal stress does not provide a fully satisfactory explanation.

In order to correlate our research data on "Creep" and the behavior of these metals in actual service, reference marks have been made on some of the high temperature parts of turbines now going into service, with the intention of checking these points after various periods of operation. In this manner, the next few years will provide valuable data on this important subject which have hitherto been totally lacking.

F. C. NORTON: The author is to be complimented on the scope and arrangement of the paper.

The numerous illustrations of a great variety of boilers, and the plots, showing the established trend of practice in leading features of operation, make the paper a convenient reference in considering new power plant design.

The concluding paragraph states the relation between utility plants and industrial installations very clearly, especially as regards steel plant service.

The developments in utility plants are not yet crystalized into standard designs, but the program is toward the elimination of the conventional boiler, with the substitution of much more effective water walls, superheaters, economizers, and air heaters.

This progress seems to be in line with desirable practice for steel plants, and advantage will undoubtedly be taken, by them, of the utility developments.

Extreme high pressures and temperatures do not seem to be advisable at present, under steel plant conditions.

A well balanced steel plant producing highly finished steel from raw ore, requires large amounts of power, as well as large amounts of process steam, including steam for heating buildings.

The use of power from outside sources, may or may not result in unbalanced conditions in the use of otherwise waste fuels, or waste heat, resulting from metallurgical operations.

In general the balance between process steam and steam for power (if generated at steel plant), is subject to the widest variation with production schedules and weather conditions. Each individual plant requires special treatment as to means for steam and power development.

The decision as to the advisability of generating power within the steel plant as against the purchase of outside power, will depend largely upon the fact that very large amounts of steam are required, even if no power be generated, and the extra investment in boilers and generators for power purposes may be well justified, particularly if waste fuel must be used. If conditions are such, that the power can be generated to a large degree, from waste fuel (or waste heat), it is evident that the steel company should generate power and all matters pertaining to power generation, become part of the business of making steel.

The paper implies that large steam turbines will be used in steel mills and this seems to be the present trend.

Very interesting developments are under way to increase the use of local steam power particularly the development of high back pressure non-condensing turbine.

The paper refers to the use of such turbines for "topping" in order that old low pressure steam power equipment may get a new lease on life at low investment cost.

The paper does not sufficiently emphasize the point that the same unit may supply all process steam at low pressure, and generate power at a very low cost, as a by product.

Should the boiler pressure be high enough and the process steam be at moderate pressure, it may be possible to get a credit for power, which will equal the coal cost of the low pressure steam when the purchase of power is the alternate.

In this case, the exhaust heat of the turbine is used in the mills, while condensing turbines reject the exhaust heat to waste water.

Under these conditions, a proper use of non-condensing turbines may prolong the life of low pressure engines and turbo generators, and force the scrapping of old low pressure boilers.

The recovering of waste heat from metallurgical furnaces offers very attractive features, particularly as applied to open hearth furnaces.

The novel step would be the use of economizers instead of waste heat boilers.

The economizers would be supplied with pure condensate water under high pressure, which would be circulated in a closed system through heat exchangers.

It is possible that all feed water might be heated by waste heat, avoiding the bleeding of main turbines, since it is evident that no system of bleeding steam (with consequent loss of capacity for power), can compete with the use of waste heat for feed water on a fuel cost basis.

The paper under "Feed Heating" states the basis of economical feed water heating quite clearly, in a broad sense, not limited to bleeder systems, i.e. "This permits the maximum of energy to be extracted from the steam before it is used for feed heating."

This point of view has many advantages, as compared to the conventional "Regenerative" idea.

The general basic principle of the use of pressure reducing turbines is obscured by the use of the term "pounds" of steam per KW hour."

It is much simpler to use the inverse term "Kilo watts per thousand pounds of steam."

For example, take a pressure reducing turbine with a steam rate of 50 lbs. per KW, which exhausts into a condensing turbine having a steam rate of 20 lbs. per K.W.

The high pressure unit seems to be inefficient, but if we take the inverse rates of 20 K.W. per M. Lb. for high stage and 50 K.W. per M. lb. for low stage, we have 70 K.W. per M. lb. combined, (or a steam rate of 14.28 pounds of steam per K.W.).

Properly speaking, the high pressure unit does not use any steam, since the exhaust is used elsewhere, after passing through the turbine, but it does generate power during the passage.

From an operating point of view, in a complicated system, the use of the term "Kilo Watts per M." is a much better unit as is proved by experience with such a system.

It will be noted that there is a close logical relation of the remarks about feed heating and the use of pressure reducing turbines.

The desirable thing is to secure the utmost power from a given amount of steam (i.e. fuel).

In many cases, with old plants, where low pressure units do not permit bleeding, a considerable gain may be made by using some of the exhaust of high pressure unit for high temperature feed heat and if non-condensing units exist, the exhaust steam may be used for low stage heat. The non-condensing unit operates tandem to the high pressure unit, giving good economy.

Actual experience with a boiler and power plant,

which was installed in 1928, and began operation in 1929, may be in order as illustrating some of the points brought out by the paper.

The steam pressure chosen was 400 lb. nominal steam temperature, 700 deg. F.

In 1928, limitations of riveted boiler drums and the properties of materials at high temperature, made the design a conservative one.

On a present day basis, a much higher steam pressure and perhaps, higher steam temperature would still be conservative, because of the development of welded drums.

This plant consisted of 6—2000 HP. boilers supplying steam to two 18,000 KW turbines, three blast furnace blowers and a battery of six evaporators.

All auxiliaries are driven by squirrel cage A.C. motors. The main turbines are bled for feed heat.

The evaporators returned the condensed 400 lb. steam to the boilers at a high temperature.

This arrangement gave a closed feed water system and required 5 to 7% make up which was condensed from 150 lb. evaporator steam.

The plant operated in this way up to the end of 1936, or eight years, and the steam pressure was never off the boiler house during this period.

In January 1937, a pressure reducing turbine of 7500 KW capacity was started and it has been in continuous use for about 9 months with no trouble.

This turbine has carried loads varying from 8000 KW to 2000 KW depending on demand for 150 lb. steam.

The introduction of this turbine caused the use of filtered water make up so that the boiler feed was from 35 to 50% filtered water.

Under these circumstances it was necessary that the filtered water make up be heated to 300 deg. or higher before going to boilers and three of the former evaporators were converted into closed heaters, using 150 lb. steam from exhaust of high pressure unit.

An old turbo generator was used to supply steam to an old open heater at 212 deg. F.

This installation is referred to in the August 1937 Issue of Iron and Steel Engineer (giving a paper by Mr. A. G. Darling. The figure 13 of this paper shows a diagram of the system.

The operation of the whole installation has been remarkably good and Mr. Darling's statements have been fully confirmed.

The unit was started under maximum load conditions and the turbine superseded the evaporators without any difficulty. Since the 150 lb. steam demand exceeded 400,000 lb. per hour the possibilities of trouble were great, but there was no disturbance of steam or power.

The boilers have operated without serious scale or other troubles, and the high temperature of feed water undoubtedly, protects the boilers.

The boiler pressure being 400 lbs. and exhaust pressure 150 lbs. the amount of power per M. lb. steam is about 20 K.W.

An up to date plant should develop nearly double this by product power.

Further steps are in progress at this plant, which are in line with the modern trend according to the paper.

The capacity of boiler house has been limited by the failure of air cooled brick walls to endure the excessive use of coal. This large use of coal was not contemplated at time of installation.

Two boilers (out of 6 total) are being fitted with complete water cooled walls and hoppers to allow the units to rim at about double the present steam output per unit.

These changes are demanded by the great increase of power required by more highly finished steel.

The development of this plant leads to a self contained steam and power system with ample provision for future extension.

Association Activities

CHICAGO

March 15, 1938

STEEL FOR AUTOMOBILE HARDWARE

By E. J. Hanson, Works Manager
Ternstedt Division
General Motors Corporation
Detroit, Michigan

PITTSBURGH

March 25, 1938

USE OF RELAYS FOR CONTINUITY OF HIGH VOLTAGE SUPPLY FOR STEEL MILLS

By E. H. Bancker, Central Station Engineering Dept. and R. H. Kaufmann, Power Generation and Transmission Dept., General Electric Company, Schenectady, N. Y.

PHILADELPHIA

March 5, 1938

PROGRAM OF SYSTEMATIC MAINTENANCE FOR DIESEL ELECTRIC LOCOMOTIVES

By L. J. Bray, General Foreman, Locomotive Shop, Bethlehem Steel Company, Bethlehem, Pa.
C. E. Kew, Locomotive Inspector, Bethlehem Steel Company, Bethlehem, Pa.

BIRMINGHAM

March 28, 1938

MOVIES—"Heat and Its Control"—Courtesy Johns-Manville Corporation.

FORTY YEARS

By PROF. W. TRINKS
Professor of Mechanical Engineering
CARNEGIE INSTITUTE OF TECHNOLGY
Pittsburgh, Pa.

Presented before the Pittsburgh District Section, A. I. & S. E. January 26, 1938

▲ MANY members of the Society will have wondered why forty years were selected as the span of time which is to be considered this evening. The reason is very simple. In October 1897 (that is to say, a little more than forty years ago) my student days came to an end, and I secured employment in the Ruhr district, in the center of the German coal and steel industry. Since that time I have followed furnace engineering and rolling-mill engineering both in creative practice and in teaching.

Before entering into the heart of the subject, we may well cast a glance at the methods by which iron and steel are produced. In doing so we find that we charge iron ore, coke, and limestone into the top of the blast furnace, blow in heated air near the bottom, and withdraw slag and iron, just the same as we did forty years ago. We charge liquid iron into a converter and blow air through it, just as we did forty years ago. Or else, we charge pig iron and scrap and limestone into the open-hearth furnace, and then blow flame across the charge, just as we did forty years ago. And we compress and elongate ingots, blooms, and bars between revolving rolls, just as we did forty years ago. From this brief comparison we judge that the metallurgists have given us no widely-used new processes In the last forty years. Please note the words "widely-used" for we have new processes, among them the Aston process for making synthetic wrought iron, and the electric melting and refining process.

But, and this is important, if we compare a steel plant or a rolling mlll of forty years ago with a modern plant, 1937 model, we cannot help being impressed by the vast differences which we observe at each and every turn. Although the basic processes are the same, far-reaching changes have taken place, and these changes have been caused mainly by the work of the mechanical engineer and of the electrical engineer.

EFFECT OF THE WORK OF THE MECHANICAL AND ELECTRICAL ENGINEER

An outstanding example will illustrate the preceding sentence. Forty years ago the reciprocating steam engine reigned supreme as the driving power for rolling mills. Water wheels were out of date, except in a very few out-of-the-way localities, and no other power was available. In order to use steam engines, we had to have steam piping, and boilers, the latter not too far away, usually in the center of the mill. Large mills had several boiler plants to which coal had to be delivered and from which ashes had to be removed. Where fuel economy was an object, the exhaust steam was condensed. In such cases we had to provide supply lines for the cooling water and sewers for the water discharged from the condenser. We also had to provide reciprocating air pumps for the condensers. When the mill was shut down over Sunday, the steam was left in the pipes, because leaks were sure to occur if the pipes were allowed to get cold and contract. In many mills, waste heat boilers were used in connection with the heating furnaces. Their presence, attendance, and maintenance added to the general confusion.

Electrical power transmission has changed this picture. Today, modern mills are driven by electric motors, which for protection against scale dust are housed in separate rooms. Power is generated in a central station which is located at the most convenient place for delivery of fuel and nearness to water. Usually the power plant is near the blast furnaces, in order to shorten the length of bulky pipes carrying blast-furnace gas. Although the steam turbine is today the standard prime mover, its position was at one time challenged by the reciprocating gas engine. From an historical standpoint, the story is interesting. The gas

Professor W. Trinks, addressing more than 800 members and guests of the Pittsburgh District Section, Association of Iron and Steel Engineers, January 26, 1938.

ARS of ENGINEERING in the ROLLING MILL INDUSTRY

engine driven blowing engine for blast furnace use was developed near the turn of the century and turned out to be a great fuel saver compared to the old steam engine. Naturally, the blast furnace gas engine was transplanted into the power plant, where similar savings were obtained. However, the gas engine was expensive, required much floor space, and came quickly to the end of its evolution, while the steam turbine marched on, thanks to higher steam pressures, higher superheat, better boiler and combustion engineering, regenerative and reheating cycles, better materials, better design, better vacuum, larger units, better condensers. Compared to the rolling-mill engines of forty years ago, which used four to six pounds of coal per horsepower hour, the modern steam turbine uses less than one pound of coal per horsepower hour. The direct use of high pressures and of high superheats in rolling-mill engines has been tried, but lubrication troubles and pipe-line troubles acted as deterrents, not to mention the condensation losses during shut-down periods. Steam pipes, exhaust pipes, condensers and their water lines, all those parts were always in the way; whereas an electric cable can be put almost anywhere without being in the road. Condensation losses have disappeared, and the power requirements of the mill are readily determined by electrical instruments, whereas with steam engines, continuous indicators had to be used. In measuring the work done per ingot by a twin tandem compound reversing engine, we had to use eight continuous indicators. Aside from the fact that engine indicators are not instruments of precision, it should be mentioned that usually twenty ingots had to be rolled before one complete set of cards was obtained. Indicator strings would break, the paper would tear, a pencil point would break, someone would forget to start his indicator, and so forth.

The development of a system of electric driving consisting of a motor-generator set with a heavy flywheel, the D.C. generator supplying current to drive the main mill motor, but controlled by varying the comparatively light field current in the generator rather than the heavy armature current in the mill motor, has enabled us in blooming mills to roll the first few passes slowly and with uniform torque, whereas the variable torque of engines caused the ingot to go through the mill like a shot.

We must not, however, conclude that all steel plants have changed over from individual steam drives to electric drives. Where fairly efficient, and well located, steam drives are in existence, it is often difficult to justify the change-over to electric drive; this is particularly true in sections where fuel is cheap and which are subjected to frequent flooding. After a flood, steam plants are going again in a few days, whereas weeks are occasionally required with electric drives.

A second, equally great change strikes the observer of forty years ago and of today; I refer to the number of men around a mill. Forty years ago the mill was crowded; men were everywhere, around the furnaces, on both sides of the mill, on the hot beds, at the shears; they were pushing, pulling, lifting. In the modern mill, the plate, strip, or bar moves through the mill as if acted upon by magic forces. As a consequence of the perfection of mechanical handling devices which are operated by electric motors, a few men in an elevated control booth do work which, forty years ago, required almost a regiment. The development has gone on in a cumulative manner. The engineer reduces the man-hours per ton; the men ask for shorter hours and higher wages, whereby the engineer is spurred again to reduce man-hours per ton, and so forth; however, not *ad infinitum*, because there is a limit to the reduction of man-hours per ton. When we reach that limit, increases in wages must necessarily mean higher cost per ton of steel. As a matter of fact, recent wage scales have already increased the cost of finished steel.

THE HEATING OF STEEL

Entering into the specific results of engineering, we find that in the method of heating the steel for rolling, much has been accomplished. While the regenerative soaking pit furnace still predominates, other types of pit furnaces are rapidly coming into use, such as the recuperative pit with horseshoe flame, and the round pit furnace. Careful engineering was required to make the modern pit furnaces the success which they have turned out to be.

It certainly is a far cry from the old coal-fired batch-type heating furnace to the modern gas-fired continuous furnace. Our coal-on-the-grate furnaces of forty years ago were worked with draft, that is to say a partial vacuum, in the furnace. The steel was unevenly heated, and scaled so rapidly that the steel bars were rested on a sand bottom, which liquefied the scale by the formation of ferro-silicate and permitted it to be drained off into little scale-pot cars. The fuel consumption was atrociously high, and so were labor costs. Both of these cost items were perceptibly lowered by the introduction of the continuous pusher-type furnace. By adapting the length to the output, engineers could use the hot products of combustion for preheating cold steel, whereby the fuel consumption per ton took a big drop. And the circumstances that the cold stock was always charged at one place, while the heated stock was always discharged at another, but invariable place, permitted vast economics in furnace attendance as well as in cost of transporting the heated stock to the mill.

It is true that not all furnaces can be made of the continuous type, because some mills, particularly large mills, require varying shapes and sizes of stock that do not lend themselves to being pushed through a continuous furnace. For batch-type furnaces, heating materials of that description, charging machines and manipulators have been designed which reduce the cost of labor.

Later developments showed that in simple continuous furnaces most uniform heating and greatest fuel economy do not go together, at least not for thick sections. Fuel economy was at first sacrificed to obtain uniform heating, and lightly heated soaking zones were later introduced to bring back fuel economy. For the same purpose a great deal of engineering was done with recuperators. Metallic recuperators have come and have gone, but they are staging a comeback; and it is quite possible that they will find widespread application. It is only within the last few years that we have learned so to shape and support the parts of metallic recuperators that neither expansion nor creep can destroy them. The principle introduced eighteen years ago by the speaker, of using heat-resisting alloys at the hot end of a recuperator while the cooler end is built of cheaper material, is now used quite freely.

Recuperators of refractory material have likewise been improved, and those built up of silicon carbide tubes have given a good account of themselves.

ENGINEERING WORK IN THE DEVELOPMENT OF DETAILS OF ROLLING MILLS

Forty years ago, rolling mills were very crude machinery, and some mills deserve no better name even today. However, much engineering has been done, and the end is not yet. Formerly the mill pinions were rough castings, the teeth of which were made tolerably smooth by "gear shield", by which is meant a heavy grease of the consistency of cold tar. Machine-molded pinions were slightly better than pattern-molded pinions, but the difference was not worth crowing about. For higher mill speeds, pinions with machined teeth became a necessity, and a number of different machining methods came into being. With well-machined pinions we could use a lighter lubricant, and pinion housings had to be made oiltight.

The use of electric motors for main drives was the reason for another development. If electric motors are to operate at the same angular velocity as the mills, they are big and expensive. It is usually cheaper to install a high-speed motor and to interpose a train of gears with either a single or else a double reduction set. At first, engineers followed custom or habit and made these reduction gears of the herringbone type; that is to say, of double-helical shape. Gradually, very gradually, it dawned upon them that the single-helical gear is preferable if we use practically frictionless thrust bearings. Most new installations are equipped with single-helical reduction gears. All of these gears are enclosed in oiltight casings. Much engineering work has been done on the lubrication of these gears.

Forty years ago, the couplings which connected the ends of the drive spindles to the rolls were the "wobblers", which in blooming mills had to have much clearance to permit raising and lowering the top roll. The result was a tremendous bang at every reversal of the mill. The impact not only could be heard for miles, but was extremely hard on the mill parts, causing wear and breakage. Twenty-five years ago, the wobbler couplings were just beginning to be replaced by universal-joint couplings. Today, no blooming mill would be installed without the latter type of coupling. Other "flexible" couplings are becoming common in other kinds of mills.

While pinion necks have been well lubricated for many years, the same cannot be said of roll necks. Forty years ago the standard method of lubrication was a piece of suet so placed that the friction heat of the bearing would melt some of the grease and cause it to drip on the surfaces to be lubricated. Bearing pressures were so high and so variable in intensity and point of application that high-grade lubricating methods appeared to be out of the question. And so we got along with tallow lubrication, and a big stream of water on the neck, for the purpose of washing away the heat generated by friction. It took engineers a long while to remedy this almost-intolerable situation. During the war, bearing metals such as copper and tin were exceedingly scarce in Germany, with the result that ball bearings, roller bearings, and wooden bearings were given extensive try-outs. Although the early bearings caused some trouble, the result were sufficiently encouraging to stimulate the use of such bearings in other countries. The comparatively sudden swing towards roller bearings right here in Pittsburgh in the early 20's is remarkable, in view of the fact that roller bearings of various types have been used on roll necks since the turn of the century in New England. The wood bearings suffered from lack of homogeneity and were soon replaced by bakelite bearings. The use of this material was initiated near Pittsburgh, and has spread over the whole world. In Germany it is used very extensively, because both phenol and formaldehyde, from which the bearing material is made, can be produced from raw materials found at home, and because water does the lubricating; no oil is needed. The use of flood-lubricated roll-neck bearings is of still more recent origin. The Morgan Construction Company of Worcester, Massachusetts, deserves a great deal of credit and praise for having developed this bearing to a point where it could be put into practice.

Table rollers years ago were driven by a small double-cylinder steam engine through a lay shaft and bevel gears. The gears were not enclosed, and they threw oil all over the place. An intermediate step in improving the drive was placing the gears in a trough of oil, with a cover. Later, they were fully enclosed, and lubricated by oil flowing through a pipe to each pair of gears. Many table rollers are now driven by individual motors.

If we may include the production of proper lubricants and the cleaning of used oil among rolling-mill engineering, then we must admire the progress which has been made. Large underground catacombs have been provided, in which oil coming from all parts of the mill is collected, freed from water and dirt, and stored, ready to be pumped back for renewed service in the mill. And petroleum chemistry, with its far-flung research, has given us lubricants of very superior qualities which were not thought of forty years ago.

CONTINUOUS MILLS

Forty years ago, the continuous mill was already thirty years old, but was used only here and there. It was driven from a steam engine by a continuous belt slung around consecutive pulleys, or more often by a lay shaft and bevel gears. In many continuous mills, both types of drive are used today without change. However, these drives do not permit change of speed ratio between stands, except by a change of gears or pulleys. On the other hand, electric motor driving of each individual stand has introduced a wonderful flexibility, but it has also considerably increased the first cost. The electrical controls must be such that the speed of each stand can be adjusted; at the same time, change of line voltage must not change the speed relation of the various stands. The flexibility which this method of driving offers has made it possible to get a new section into production after a very small number of trial bars.

In continuous mills, the introduction of alternating horizontal and vertical stands has proved to be a great step forward. Used at first solely for edging purposes, stands with vertical rolls now have grooves provided in them for reduction as well as change of shape. By making the vertical stands adjustable vertically and horizontally, we have been enabled to change quickly from one section to rolling a different section, without changing rolls. With business as it has been in the last few years, the possibility of changing quickly from one section to another has been very valuable. Thirty years ago, a mill rolled the same section from Monday morning until Saturday afternoon. Today we roll nine or ten different sections in the same period of time. In applying the principle of adjustable vertical rolls to rod mills, we have been enabled to use the same set of rolls for a long period, by switching from one set of passes to another fresh set of passes having the same size.

STRUCTURAL MILLS

The last forty years have seen great changes in the rolling of structural steel. While channels and angles are rolled just about the same as they were forty years ago, I-beams and H-beams are rolled on universal mills. As a matter of fact, neither large H-beams nor wide-flanged I-beams could be rolled forty years ago, because the method of rolling beams on two-high or three-high mills requires a minimum taper on the flanges, and because in wide-flanged shapes that taper causes great variation in thickness from root to tip of flange, which variation in turn causes great temperature differences in the beam delivered by the mill. Attempts to roll such beams on ordinary two-high or three-high mills always ended in disaster on the hot bed, where the beams warped and twisted so that they could not be used. Grey, an Englishman, experimented with the rolling of such beams in this country, but did not produce commercially usable beams. However, he received a call to Luxemburg in Europe, where a successful universal mill was built and rolled commercial beams soon after the turn of the century. From there, Grey was called back to the United States, where two Grey units were erected in Eastern Pennsylvania about 1906.

In 1914 Puppe, a well-known German rolling-mill engineer, started a mill in Peine, Germany, where he introduced the method of rolling wide-flanged beams with alternately inclined and parallel flanges. This method was modified by Oberg, of Pittsburgh, who introduced the five-stand mill, in which the first four stands work with inclined flanges, and the finishing stand does little more than bending the flanges into final shape. Universal beam mills are now in operation in four steel plants in the United States. Their great influence upon the structural business may be judged from the fact that almost two-thirds of the steel tonnage of a skyscraper consists of wide-flanged beams.

SHEET AND STRIP MILLS

In the year 1921 a representative of the foremost builder of continuous mills in the United States read a paper, right here in this hotel, on the subject of continuous mills. He closed with the sentence: "They (the mill builders) do not hesitate to predict that, whenever a specialty in hot rolled steel reaches the required point of standardization and demand, a continuous mill for that specialty will be forthcoming." Upon being asked whether there was not sufficient demand for sheets to warrant his company's building a continuous mill for rolling them, he had to admit that the continuous sheet mill had not yet arrived. Since then, it has arrived, bearing the name "wide strip mill". The development was very gradual at first. Engineers felt their way slowly from hoops towards wider and wider strip, both in hot rolling and in cold rolling, and did so without much use of mathematics. The value of small roll diameters was recognized at an early date. In fact, it had been expounded in patent specifications before the beginning of the forty-year period under consideration. The four-high mill with small working rolls is usually considered to be a very modern achievement, but we are taken down a peg or two when we realize that it was described by a Swedish author several hundred years ago. It was resurrected in this country not for strip mills but for plate mills; to be more specific, it was selected by Pittsburgh engineers because it was considered impossible to produce a chilled roll of the size which would have been required for a three-high mill.

The problem of roll-neck bearings did not bother engineers in the hot rolling of strip, because rolls and bearings were watercooled, and because frequent adjustment of the rolls, due to bearing wear, was not considered a hardship. In the cold rolling of thin and wide sections, friction in the neck bearing, and skin friction between rolls and strip had to be tuned to each other in such a manner that the rolls would stay cylindrical. Since that turning is seldom perfect, auxiliary means, such as heating or cooling certain parts of the rolls, including the necks, were used, and are so used today. As previously mentioned, the value of roller bearings for increasing the speed of rolls in cold rolling was appreciated around the turn of the century, and bearings of the cage type and of the full complement type were used in New England. Wider and wider strip was desired for automobile fenders, hoods, bodies, for refrigerators, washing machines, metal furniture, and still other uses.

The first modern wide strip mill was designed here in Pittsburgh in 1926, and was started on Thanksgiving day of 1926 in Butler. Although the reversing stand which preceded the continuous stands in that mill had been abandoned for the rolling of thin strip, it was recently duplicated, with improvements, by a modern strip-plate mill in the Pittsburgh district. At present all stands in a modern strip mill are of the four-high type, except the scale breaker. If the present tendency towards still wider strip continues, we may have to drive both the working rolls and the backing rolls, for the purpose of avoiding the use of larger diameters of working rolls. And in cold rolling we may be compelled to support the working rolls laterally or else to go back to the cluster mill and support the backing rolls by still larger rolls. This type of mill was invented in Germany and is now being tried in the United States.

In discussing the engineering of the strip mill, it would be unfair not to mention some of the earlier attempts. One of the earliest hot mills was operated in what was then Austria and is now Czechoslovakia. In order to limit output, a slow speed was adopted, with the result that the strip left the mill a wedge, thin at the front and thick at the rear end. The strip was cut into short lengths which were sorted for thickness. The mill was finally shut down, because the output could not be absorbed. Later on, a semi-continuous, or tandem, mill was built in northwestern Pennsylvania; it failed because of a combination of circumstances, among which were errors in design. Still another semi-continuous, pack rolling mill was operated in Kentucky. While this mill was a step forward in many respects, the pack rolling did not permit taking advantage of the greatest metallurgical advantage of the strip mill; namely, the freedom to select the composition of the steel, without fear of stickers.

In cold rolling ,three types of mill are now in common use; namely, the pull mill with very small not-driven working rolls, the single stand reversing mill with driven rolls and strong reels for exerting front and back tension, and finally the three-to-five-stand tandem mill. Each of these types has its field of application, and each type required the exercising of considerable engineering skill. In general, the pull mill is limited to narrow and thin strip. The reversing mill is adapted to changing orders of wider strip, while the tandem mill excels in mass production of standard material. Welding of coils and cold rolling these welded coils has contributed to its success.

The strip mill has called for much engineering in auxiliary equipment, such as flying shears, coilers, continuous pickling tanks, welding machines, trimming shears, roll grinders, and still other machinery. It has also called for careful electrical engineering, because in the two-high reversing reversing mill the speeds of the reels and of the mill must be so tuned to each other that the proper tensions in the entering and delivered strip are maintained.

The development of the wide strip mill had its repercussions in the old type sheet and tinplate mill. The difference in man-hours per ton between the strip mill and the old-fashioned mill was so enormous that the old sheet mill had to be remodled or else give up the ghost. The remodeling process included automatic moving of sheet bars through the furnace, automatic transportation from furnace to mill, semi-automatic tables at either side of the mill, automatic roll polishers, doubling machines, and the like. A great deal of ingenuity has been shown in the design of this equipment. In spite of this expenditure of engineering skill, the general prophecy is that the old type of steel mill is doomed.

In all kinds of steel production, the emphasis has shifted to quality rather than mere tonnage. This means that the engineer has to provide chipping and deseaming devices, scale breakers, descaling sprays, special non-oxidizing atmospheres for furnaces, together with automatic control; and especial care has to be used in roll pass design to avoid laps, fins, or the rolling in of scale, while guides and conveyors have to be so designed as to prevent scratches on the surface of the rolled bars. The use of pyrometers for controlling the temperature of the steel not only in the furnace but in the rolling mill has become very general. Bars are in many cases held on the tables until the pyrometer shows that they have reached exactly the temperature required for producing the desired grain size or crystal structure.

Considerable ingenuity and engineering talent were bestowed on the problems of die rolling. It has always been a fascinating subject, because it takes us right into the heart of rolling difficulties if the projections or depressions of the die-rolled bars are to be fixed distances apart with close tolerances, because of the phenomenon of forward slip. For we have as yet no method by which the ratio of bar speed to roll speed can be computed theoretically for other than rectangular sections. The problem of rolling rounds of alternately varying diameter in mass production was solved by rolling deliberately with a fin or flash and then trimming the latter off in the cold state. However, such bars are now usually rolled in a gap mill, because there they are subjected to a more uniform forging action; they are roll-forged, as the expression goes. Quite recently much thought has been spent on the combination of die rolling and drop forging. Bars are die-rolled in such a manner that drop forging can be accomplished with a smaller number of blows, and with less flash that has to be trimmed off.

TUBE MILLS

Much engineering skill has been shown in tube mills. While butt welding, lap welding, and piercing of round billets are more than forty years old, new developments have taken place. We now have double piercing, which is really a misnomer, because the blank, in entering the second pass, has already a hole in it. We have continuous butt welding; we have elongators, in which the stationary guides of ordinary cross rolling mills have been replaced by quickly rotating disks which pull the tube blank forward. The design and material of the elongator disks have required considerable thought. It may well be mentioned here that the elongator was invented by Sam Diescer here in Pittsburgh.

Several other processes of rolling tubes over a mandrel have been perfected, among them a modification of the Mannesmann Pilger mill, with the outstanding difference that the reduction is accomplished on cold material and that the rolls reciprocate while the tube blank is stationary.

The old German Ehrhardt process, known as the push bench method of making seamless tubes, has been improved. As may be expected, the push mandrel is now driven by an electric motor, whereas it was, in former years, pushed by hydraulic pressure. The reducing mills which are used to lengthen the tube blanks which come from the push bench have been improved by using four rolls per mill and by placing the stands smack against each other. If that is done, tension can be exerted on the tube blank without reducing the yield perceptibly, it being understood that the ends of the tube blank are not subject to tension and have the wall thickness of the tube increased. The theory of the reducing mill is still rather unsatisfactory. This mill is one continuous mill in which we still use a line shaft and gear drives (at least in this country). Since the draft is not adjustable, and the theory is far from being understood, a great deal of experimenting is necessary for find the right draft for a given gear ratio, or vice versa.

Expanding mills for enlarging tubes have been perfected. The outstanding engineering feat in this type of mill is probably the use of a tension mandrel. It does away with the vibrations which are caused by the buckling of a compression mandrel. It is evident that in piercing we must use a compression mandrel, but that in what we call the second piercing, and also in expanding, we can use a tension mandrel.

In the production of non-ferrous materials, bars and tubes are now commonly made by the extrusion process, which has replaced the rolling process except for those alloys which cannot be hot warked and which are therefore rolled cold. In the production of iron and steel bars and tubes, extrusion has been limited to very short bars such as the valve stems for internal combustion engines, and to tubing. The extrusion of steel tubes is being practiced in Germany and Japan. As may be expected, short life and high cost of the dies are the principal obstacles in the road of replacing rolling by extrusion.

WIRE MILLS

In the rolling of wire, nothing radically new has occurred in the last forty years. The Garrett mill and the continuous Bedson-Morgan mill were both in existence forty years ago. However, engineering has left its impression on the wire mill also. Speeds have been increased until the wire rod is today delivered at or even above 4000 feet per minute. There is not much difficulty in rolling at a high speed, but engineering difficulties arise in designing and operating the reels which are to receive and coil the wire rod at these extremely high speeds. For soft steel we still employ a square-oval-square series of roll passes, but for hard steel it had to be modified. The greatest progress in wire mills has been made in handling and labor-saving devices. All these devices concern the material which has already left the mill.

In this country we do not as a rule run more than two strands of wire through one mill, while in Germany as many as four strands pass through simultaneously. Some difficulty then arises by roll spring. Whenever two or three strands are out, the remaining strands become smaller, because the rolls spring together.

ENGINEERING, PAST, PRESENT AND FUTURE

Engineering has changed in the last forty years. At the beginning of that period, Pittsburgh had several consulting engineers with large offices and many draftsmen. At that time, rolling mills were small, and there were many of them; they were too small to afford competent engineering staffs of their own. On such ground, consulting engineers prospered. Mergers and business reverses have causes the small mills to disappear, or else to become part and parcel of a large organization which had thoroughly competent engineers. Today the work which used to be done in the large offices of consulting engineers is done by engineers employed or retained by the large steel companies.

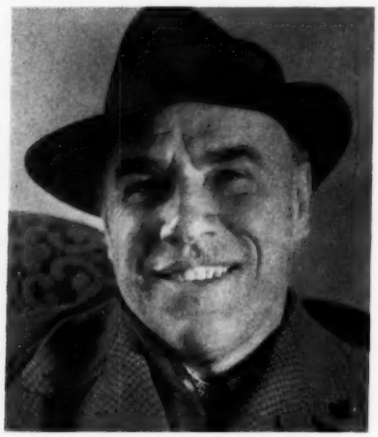
While engineering is still an art, every engineer is doing his best to make use of science and theory as far as his work of design, construction, testing, and operation is bettered by the use of science, which latter after all is only coordinated knowledge. It behooves us, therefore, to review briefly what progress the theory of the rolling mill has made in the last forty years. That progress is wonderful, and yet it falls far short from giving us a complete theory of rolling. The theory of rolling rectangular bars between cylindrical rolls is very well understood, and this theory has been a great help to us in the design and operation of strip mills. But the flow of metal in the rolling of shapes is even today what a friend of mine has aptly called a "guessing contest." It *must* be just that, because speed of deformation, temperature, and composition of steel bar, temperature distribution in bar, and roughness of roll severely affect the flow of metal. We have no yardstick for roughness of roll and we have no knowledge of the effect which a change of composition of the steel has upon the friction between roll and bar. Much remains to be done in this respect.

The power requirement of a rolling mill, or in other units, the roll train resistance, has been given much study, and much progress has been made in predicting the roll train resistance for new mills. It was mentioned in an earlier part of the paper that electrical measuring instruments have been a great help in securing data on this subject. It is to be regretted that the large electrical companies have refused to cooperate with engineering societies in the attempts of such societies to analyze their results and to put them into shape for general use.

An outlook into the future is hazardous. After seeing the great progress which has been made, we may be inclined to feel like the clerk in the Patent Office who resigned in 1885 because, he said, everything worthwhile had been invented and there was nothing left to invent. There are, however, many problems ahead of us, such as direct rolling from molten metal, extrusion of steel bars, the rolling of strip by low-cost mills, and still others. The Krause mill is an attempt to solve this last-mentioned problem, and may become a serious competitor of the present-day strip mill.

As previously said, it is dangerous to prophesy; however, I am firmly convinced that the Pittsburgh district will maintain its supremacy as the center of inventions in the rolling mill industry and that members of this Association are even now actively engaged in engineering work which will make its influence felt as far into the future as forty years from now.

ALTERNATING



C. J. HOLSLAG

HISTORY

▲ HISTORICALLY the Electric Arc melting furnace is the Father of all arc melting and was used single and double carbon ahead of the metallic arc coincident with the arc lighting period. The present metallic arc is a miniature Electric furnace with all its derivations such as alloying slagging, fluxing, keeping air away, introduction of inert and burning ambient passes and control of grain structure, etc.

The shielded metallic covered electrode works best with the A.C. arc and the A.C. arc gives best results with covered rods. They are counterparts to a desirable result namely the advance of welding.

There are many derivations of the shielded arc as well as uses of the A.C. arc, such as gas enclosed single arc deposited metal, double or triple arc metallic, double gas enclosed arc with or without filler material, i.e. hydrogen flame arc popularly called the "atomic" arc generally used with Tungsten electrodes; the metallic arc covered and uncovered but enclosed in a flame; the semi-arc flash enclosed in hydrogen and also used in the air generally with a nickel rod for cast iron machined surfaces, the welding of cast iron, manganese and other alloys with A.C. and the nickel alloy and/or monel cast iron machinable weldlng, also electric brazing generally done with double carbon electrode handles.

The submerged arc system, still in its infancy, in which a bare or a fluxed electrode holds its arc under a heavy blanket of flux and slag, is also adapted best to A.C. power at the arc and makes a deposit which already rivals the results made by the shielded arc and from its protected continuous nature of deposition is already more attractive for heavy work both as to results and costs.

Alternating current shielded arc and submerged arc processes are now accepted for welding Class 1 and 2 pressure vessels. The principal manufacturers have experienced the best results with A.C. It was the good results obtained by A.C. that allowed the Boiler Code to be adapted to arc welding.

In order to introduce this paper on A.C. welding, we will sub-divide into:

A. Metallic Shielded Arc Welding.
B. Submerged Arc Welding.
C. Automatic A.C. Arc Welding.
D. Special Uses of A.C. Welding.
   1. Series Arcs.
   2. Gas Bathed Arc.
   3. Semi-Flash Arc.
   4. Hydrogen Flame Arc.
   5. Double Carbon Arc.
   6. Cast Iron and Manganese.
   7. High Frequency A.C.

First and foremost of the uses of A.C. is the covered electrode and the submerged fluxed metallic arc method and these will be treated first as they are foremost.

With this type of arc welding ten outstanding results have been accomplished. First, sound welds. Second, high speeds. Third, less first cost and less operating cost. Fourth, no A.C. blow. Five, no chipping between layers or from reverse side in most cases. Six, deeper penetration without undercutting or side wash. Seven, less dross inclusion. Eight, less gas pockets. Nine, better grain growth structure. Ten, engineered multiple wiring systems with independent control of voltage and amperage. Alternating current is now for heavy major important work the welding system used leaving D.C. for vertical welding copper alloys and such special jobs.

A. METALLIC SHIELDED ARC WELDING

The covered electrode shielded arc process which has been struggling for favor in this country for a little less than twenty years is now becoming very popular.

This process consists of covering the electrode so as to shield the arc and provide a refining atmosphere and in addition to the speed and refined metal advantages gained by this process, layer annealing is used to obtain better results than were possible by any previous means including the gas arc process or any fusion process. From a practical standpoint, it is perfectly feasible to weld a narrow "V" and do thick work with this process. With the covered electrode metallic arc, it is entirely possible and quite common practice to weld two to six inches thick and many jobs have been done twelve to twenty-four and even thirty-six inches in depth. The process consists of making a suitable "V", "U" or bell-shaped groove, either double or single, with projecting lips so as to approximately register to hold the first deposit. Immediately after making the first deposit, the combination of peening and caulking removes the dross and cleans for the next layer and forces out the deposited metal to the original dimensions of the "U" or groove. This relieves contracting strains and also by what might be described as a molecular-rearrangement, takes the internal stresses out of the deposited metal.

Continuing with a clean and smooth surface, the process consists of depositing layers one after the other, repeating the chipping, cleaning, forging and remelting.

CURRENT *Arc* ADVANCE

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NEWARK, N. J.

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refines the layer beneath it. It is not at all difficult to exceed the strength of the best steel using this process with a base deposit metal. Not only is the strength exceeded but also the other physical qualities are bettered or equal. This refining action and removal action can be accomplished by a cutting electrode, that is the cutting arc can be passed over the work, some of the metal removed, or none removed, and the final action obtained. This cutting electrode is also very essential in this process in double "V" or work that has to be sealed on the inside. The rod is used to remove the uneven, penetrated parent or dribbled welded metal and the grooves so made and filled up by the regular process herein described. It will be noticed, from a practical standpoint, that this method is apparently very easy but as a matter of fact experience and practice can only give the results described. For instance, if such a covered electrode is used, not as described above, say in a single layer or even in a double layer with the last layer expected to carry part of the strain, results, perhaps inferior to ordinary welding, may be obtained except this covered electrode can be used for speed where elongation and ductility are not required. In other words, this covered electrode can be used in amazing current densities and almost unbelievable speeds of deposit where the special physical properties desired above are not necessary. Under some conditions, both speed and desirable results can be obtained in one layer and always in two or more layers. For instance, if the work is just thin enough to be heated to the correct normalizing temperature by one or two deposits, then the desirable results can be obtained in one layer with amazing speed but this is generally only reliably possible in automatic work because both the speed and current deposit must be held constant at the correct temperature, i.e. 1150 F. Approximate results much better than ordinary welding can be obtained with an intelligent operator holding the temperature from color or at the correct value of between 1100 and 1200, the weld being made in one or more passes.

With this process, especially on thick work, a normalizing oven is necessary. This can be a temporary or permanent brick affair where the temperature is held between 1100 and 1200 and into which the object being welded is rushed when it shows signs of the heating stresses overcoming the unfinished weld deposit. Preheating in such a furnace would also help but practical consideration of being able to "set up" the work while cold generally precludes this.

The best way would be to preheat but with hand welding this is out of the question as you cannot stand near enough to work on it properly. It might be done with automatic welding but it would have to be followed with automatic caulking; that is, an automatic welding head would be followed by an automatic peening tool so that the contraction strains would not pull the piece out of alignment or crack it. These contracting strains are the necessity for an oven equalizing of the heat so that the parent metal or weld will not rupture while hot. There is no such danger in mild steel when oven cold.

Practically, manual welding is started in the morning and around 3 o'clock or 2:30 on a hot day, it gets so unevenly hot it is put in the oven, the heat turned on, until evenly at 1150 F., and then left there over-night without heat; that is, cooling slowly, taken out in the morning and work started on it again. It takes about an eight-hour day to get the piece so it requires normalizing. This is shown by the skin of the steel puckering and cracking off. It is then high time to put it in the furnace and call it a day.

When the work is all completed, the job is put in the furnace and kept at a temperature of 1150° for as many hours as there are inches of thickness in the heaviest place. It is then allowed to cool off in the oven and is ready for remelting or if completed for eternal life.

TABLE FOR HEAVY SECTION STEEL WELDING

Place Thickness	Amps.	Volts	Electrode Size	Lgth. of Rod	Lbs. per Hour	Groove Width	Lip Thickness
3/8 in.	300	27	3/16	15	5	1/2	1/8
3/4 in.	350	30	7/32	16	7 1/2	3/8	1/8
1 in.	400	33	1/4	18	10	3/4	3/32
1 1/2 in.	500	36	9/32	20	15	7/8	5/32
2 in.	550	38	5/16	22	20	1	3/16
3 in.	600	40	11/32	24	25	1 1/8	3/16
4 in.	700	42	3/8	30	30	1 1/4	7/32
5 in.	750	44	7/16	36	35	1 1/2	1/4

The usefulness of peening and caulking has been a large factor in the success of the shielded arc process. In the early stages of welding in the United States peening with arc welding was used extensively but for

a great many years thereafter it sort of fell into disuse.

The ordinary boiler chipping hammer is the best tool and a dull chisel can be used although special ground tools shaped to fit the surface arc better but not necessary. Air pressure hand caulking can be used too and an air hammer is better by far. Rather medium hard but not "forcing" blows should be used and in peening a weld, the same as caulking a riveted seam, a great deal of judgment must be used. For instance: If metal is actually forced down into cavities and imperfections closed by this method, there is more harm than good done. The idea of peening is to relieve effects of contraction of the welded metal by these means:

1. Forcing of the deposit to fill the original space and maintain the gap or "V" dimensions.
2. Stress relief by grain refinement which might be described as settling into place of the molecules while under motion due to the hammering.
3. Improvement of the metal by "working". This effect is well known but of least importance on account of the remelting of the deposit.
4. Another very important effect is the cleaning of the surface of slag or dross and peening should be done so as not to include slag in succeeding layers or flow the metal by heavy or too many blows so as to fold over itself to cause faults.

The cleaning of welds for subsequent layers is absolutely necessary but it has not always been so realized. Of course, in addition to peening and caulking there is sandblasting and other mechanical means of cleaning but probably the most popular is the chemically fluxed electrode which leaves only such dross that a hand or motor driven brush can remove.

To summarize the valuable uses of peening:

1. Stress relief by helping the molecules to settle in their ultimate position due apparently to the rattling action.
2. The flowing of the metal in a direction opposite to the contraction strains of the weld.
3. Working of the metal of the weld deposit.
4. Cleaning of the weld surface and smoothing it into shape for perfect subsequent layer deposits.
5. Bringing the welding pieces back into the exact dimensions even to one-thousandth of an inch as described.

Summary of advantages of shielded arc:

1. Better metal deposit than possible by any fusion means yet discovered.
2. Ductility and elongation equal to best "Marine" steel.
3. Elimination of oxides, nitrides, cyanides and other deleterious compounds.
4. Arc process "easy" to handle and speed of deposit greatly increased.
5. Large and heavy work made possible and more smaller work brought within the scope of welding.
6. Either Direct or Alternating Current can be used with this process.

B. SUBMERGED FLUXED A.C. ARC

The idea is to use in welding the open hearth or electric furnace method of making steel. In this scheme the metal melted by the arc is left where it becomes a part of the parent metal by fusion and the metal parts to be joined and added to by this arc welding furnace operation. For instance, referring to the multiple electrode method, two or more arcs may be combined in the one molten pool. In this method the rods may be fluxed or covered with alloying materials. The arc takes place under a blanket of slag, the slagging material being placed there before the welding starts. The metallic electrode is not necessary in this system, a filler metal can be added with alloying ores or combinations, carbon, graphite, tungsten or an non-burning away electrodes can be used especially as they are protected by the deep slag covering, which can be melted by the submerged furnace arc under the blanket of slag. The slag is similar to that used in open hearth steel making. The metal is not poured; the slag remains in place until the metal is cooled and reaches the best grain structure and density. This action can be arrested at any grain structure or hardness desired.

By this method the arc takes place beneath one or more inches of slag, and this differentiates it from all previous practice. The difference between this and all other systems is that the arc is present underneath the slag and that the result is that the weld never reaches air while nascent and the metal is not poured so that the weld has not a chance to become contaminated and the entire grain anneals to its best condition. If desired the filler metal can be combined with the alloy metal placed in the flux or slag or in the "V" or groove underneath or in the slag blanket. This system also eliminates the necessity for gas protection but combinations of gas, slag and fluxing can be effected if desired.

The apparatus for this is a combination of automatic head and heavy transformer welder as per photograph.

C. AUTOMATIC A.C. ARC WELDING

In the field of electric arc welding development has been so rapid in the past ten years that we are accustomed to consider practices which have been in effect from five to ten years, as old and established customs. It may, therefore, be stated that automatic welding of pressure vessels with A.C. is not new. However, this thought should be qualified by the statement that it is only quite recently that the demand for automatic equipment, transformers, electrodes and procedure have become generally available for industry through the developmental effort of concerns which are in the field of commercial exploitation of welding.

There are two systems of A.C. automatic welding. The heavily covered electrode and the submerged arc described in another part of this chapter. Both systems depend on shielding deposited metal from the air. Shielded arc electrodes form a gaseous envelope around the arc and a slag covering over the deposited metal. In the submerged shielded arc the slag and flux is a heavy blanket over the deposited metal and the same lack of contact with the air gives equally if not better results. In the latter system, grain refinement is due to the longer time if the deposited metal is hot. In the former system, the grain refinement results mostly from the reheating of repeated layers. In either case, the flux may contain alloying or refining compounds or elements. With either system it is practical to obtain deposited metal equal to and often superior to any metal produced otherwise by any means.

Controlled welding of the sort just mentioned elimi-

nates many of the uncertainties inherent in bare wire welding which in that case became excessively troublesome when welding currents much in excess of 250 amperes were used. With these factors removed, it was natural to go to higher welding currents with their increased electrode melting rates and at the same time obtain required penetration due to the concentration of heat by the electrode coatings.

For some time excellent work has been done with shielded arc electrodes and D.C. but there still remained a troublesome factor, magnetic blow, the effects of which were to slow down production rates and increase unit costs. Although it is possible to largely counteract the effects of magnets, it has appeared impossible to do anything about magnetic blow by changes in electrode characteristics. Since the use of A.C. would naturally largely avoid this trouble, it remained for the metallurgists to develop electrodes which would operate satisfactorily with A.C.

It is seen, therefore, that electrode development is largely responsible for making practical the use of A.C. and properly designed A.C. electrodes are likewise good when used with D.C.

In order that our story should be complete, we must not omit stating the disadvantages of A.C., but at the same time experience has shown that elimination of magnetic blow is, in many cases, of so great importance as to outweigh these disadvantages.

There is a psychological element involved in the use of A.C. which is probably inherited from the earlier days when A.C. equipment was talked about. This is a fear of shock on the part of welding operators. We call this psychological because it is actually unjustifiable since present day application of A.C. tends toward the use of such low values of secondary voltages as to make the danger practically non-existent. Voltage-reducing auxiliary attachments eliminate this objection, but, of course, add certain costs which are a necessary evil, we hope of a temporary nature only.

In the field of welding there is available a complete line of equipment for A.C. A typical installation will be described later. Transformer welding units are offered in the following sizes by the various manufacturers:

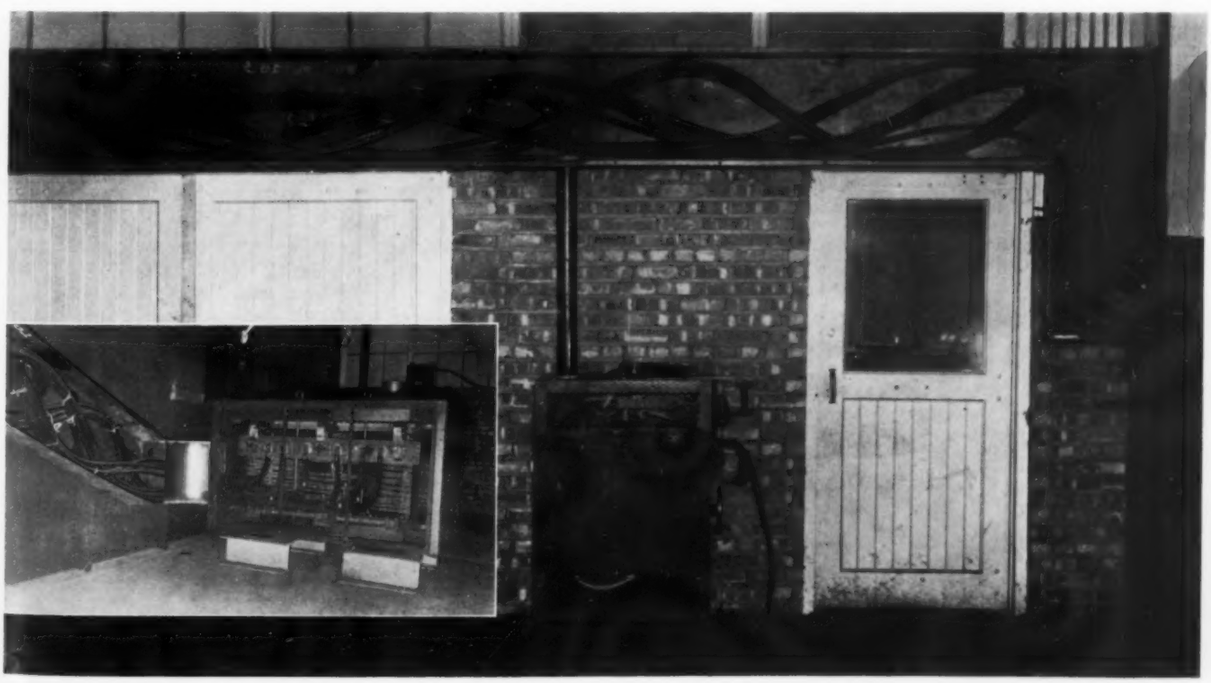
Amp. Ratings (85 deg. C.)		Oper-ation	Terminal Volts Open Cir.	Current	Range
1 Hour	Contin-uous			Max.	Min.
500	375	40	60/70/80/90/100/110	500	125
750	575	40	60/70/80/90/100/110	750	175
1000	750	40	60/70/80/90/100/110	1000	250
400	300	40	60/70/80/90/100/110	400	100
300	225	25	60/70/80/90/100/110	300	75
200	150	25	60/70/80/90/100/110	200	50
100	75	25	60/70/80/90/100/110	100	10

An extra attachment for reducing secondary open-circuit voltage to 50% of normal, or lower if desirable.

An extra attachment for high frequency in the smaller sizes down to one ampere and in the larger sizes for jump spark starting.

A welding transformer unit is essentially a high

Mother transformer and one of the twelve 600 ampere outlets (inset) of the A.C. multiple ring system installed at the Hamler Boiler & Tank Company, Chicago, Illinois.



reactance transformer with a means of adjusting reactance for purpose of current adjustment. The reactance is for the purpose of reducing the secondary voltage from the striking or no-load voltage down to that required for the arc. These values are at present approximately 80 volts and may even be as low as 65 volts at no load, to 40 volts at the arc. Besides the switches or other means of current control, each unit has a voltmeter and an ammeter and enclosed primary and secondary terminal lugs. Due to the service for which they are intended, these units are necessarily of the air-cooled type and for stationary mounting. Voltage and current reducing attachments when used are mounted on the transformers with suitable enclosures. Larger transformers may be made oil cooled. An automatic arc-welding head, to justify its name as such, is a motor-driven, wire-feeding device, with electrical control which causes automatic maintenance of the arc length irrespective of variations in electrode melting rate. Such devices also are provided with means of conducting the welding current to the metallic electrode at a point which remains at a constant distance from the arc at all times. It is always preferably in automatic welding to use electrode in continuous lengths from a reel. Unless this is done, one of the important economies of this process is lost, namely, the saving of the loss of electrode material in short ends that cannot be consumed. With the proper combination of a well-designed electrode and automatic head, no difficulty is encountered in feeding any size and type of shielded arc electrode which can be reeled without destroying its coating. For repeat operations, wire of any straight length can be employed and for regular work the electrode feed can be geared to the traverse feed thus saving complications.

Another development is the oscillating attachment by which adjustment of the amplitude, frequency and direction of oscillation of the arc may be obtained. The speed of electrode feed may be increased or decreased by a simple gear shifting device, without stopping the machine.

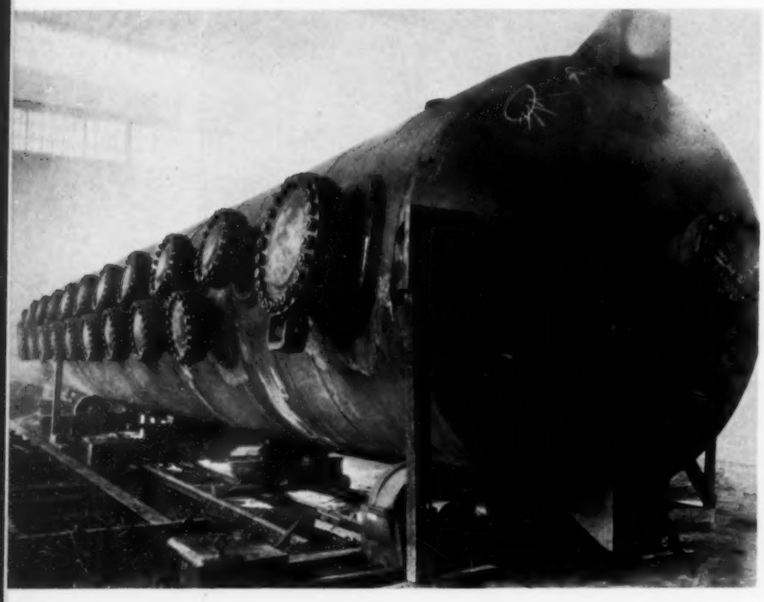
Suitable electrodes for automatic A.C. welding of Class 1 Pressure Vessels have, beside the necessary arcing characteristics, a high gas producing coating and one which provides complete slag coverage for the weld. The slag is easily removed from the weld metal after it has cooled. It is, of course, understood that the resultant weld deposit meets the physical and X-ray requirements for Class 1 pressure vessels with the minimum expenditure of effort and time.

For use with this automatic arc-welding machine, heavily coated shielded arc electrode is provided in several varieties, as required by the material and process involved. It is covered by a fabric or paste generally extruded coating heavily impregnated with fluxing ingredients. This securely adheres to the base wire, due to the properties of the ingredients used.

TABLE A

Plate Thickness T In.	Edge Preparation Fig. No.	8 Deg.	A In.	B In.	C In.	D In.	R In.	No. of Passes
1/4	8	70	1/8 − 5/32	1/8	1/8	1 1/4	....	3
3/8	8	70	1/8 − 5/32	1/8	1/8	1 1/4	...	4
1/2	8	70	1/8 − 5/32	1/8	1/8	1 1/4	....	6
5/8	9	70	1/8 − 5/32	1/8	1/8	1 1/4	....	7
3/4	9	7 to 9	1/8 − 5/32	1/8	1/8	1 1/4	5/16	8
7/8	9	7 to 9	1/8 − 5/32	1/8	1/8	1 1/4	5/16	9
1	9	7 to 9	1/8 − 5/32	1/8	1/8	1 1/4	5/16	12
1 1/8	9	7 to 9	1/8 − 5/32	1/8	1/8	1 1/4	5/16	13
1 1/4	9	7 to 9	1/8 − 5/32	1/8	1/8	1 1/4	5/16	15
1 3/8	9	7 to 9	1/8 − 5/32	1/8	1/8	1 1/4	5/16	16
1 1/2	9	7 to 9	1/8 − 5/32	1/8	1/8	1 1/4	5/16	16

FIGURE 1—Typical shell before removal of test plates. Note X-ray markings.



To apply the process and equipment described to Class 1 pressure vessels requires certain fixtures for holding the work in position and for travesting the arc across the work or vice versa, as well as material handling devices. These vary with the plant layout and are usually built to the particular specifications accompanying each individual installation. They are, however, all based on the well-known principals of rolling devices for circumferential seams and travel carriages for longitudinal seams.

Several companies now manufacture weld fabricated pressure vessels under the A.S.M.E. Code for Class 1 unfired pressure vessels. A.C. automatic arc welding is used exclusively for all seams excepting tank fittings, which are applied by hand welding with A.C. Such installations have been in successful production operation for many years.

Concerns that have been actively engaged in weld fabrication for several years, have recently equipped themselves for Class 1 pressure vessel welding. The

data given at this time is not intended as an impressive display of quantity production but is of particular interest as an example of high quality welding with A.C.

Most of the plate stock is purchased from the mill as required. This is common practice for such work. However, a small stock of light-gauge plates is kept in stock.

Often it is found desirable to have the plate edges machined at the mill, to the specified groove. All other stock can be planed on a standard type plate planer, 38 ft. long which will handle at least 4 in. thickness without difficulty.

Shells from 33 in. minimum diam. up to the largest which can be shipped, 14 ft. diam. can be rolled on the 200-ton rolling equipment. An hydraulic pressure-break takes care of the preliminary breaking of the plate edges.

The welding procedure is as follows:

The bevel or groove is a V type for thicknesses up to and including ½" and a bell shape heavier plates. Experience has proved that the angle of V-bevel and of the sides of the U-groove are an important factor in obtaining successful results. Wider angles add nothing to quality and increase costs by requiring more weld metal deposit, which also reduces net welding speeds. Narrower angles tend to produce under-cutting of the bottom layers of weld metal, thus entrapping slag and increasing the effort required in cleaning between passes and in repairing defects detected by the X-ray.

The first welding operation is the longitudinal seam. The tabulation in Table A gives the plate thickness, type of bevel (u or v) and its dimensions and the number of layers or passes. Table B gives typical welding data and includes the electrode type and diameter per pass, the corresponding welding current, arc voltage, welding speed, wire consumption and oscillation amplitude and frequency. This data applies also to circumferential seams and is irrespective of vessel diameter or length.

The order of procedure is to weld the groove full, including reinforcement at the top, then chip off the backing-up strip and reweld the back of the groove by hand filling in the weld metal that was removed in chipping off the backing-up strip, and reinforcing the weld on the back. Welding layers average ⅛" in thickness and reinforcement extends above the plate surface the amount required by the Boiler Code. This reinforcement is chipped off on all fired pressure vessels or when the customer requires it to be done on other vessels.

Cleaning between passes is accomplished by loosening the slag with a hooked instrument much like a pinch-bar. The chips are blown out and the oxides and spatter are removed from the sides of the groove with a pneumatic tool. The weld is then cleaned again with a hard wire brush.

The welding transformer for the automatic is rated 750 amps. one hour of 575 amps. continuous, 40 volts secondary. Five hundred ampere transformers are used for hand welding. No power-factor correction is applied as other plant equipment provides sufficient corrective KVA, in synchronous motor drive. Phase balancing is sufficiently well taken care of by distribution of the single-phase units on the three-phase system.

After welding, the test plates are removed and all seams are marked with the usual lead identification markers, for X-ray examination. Figure 1 shows typical shell before removal of test plates and with markings for X-ray examination. Every seam is examined with an X-ray machine. This machine is the most modern type. It is mounted on special truck for ready portability. Effects when found are chipped out, re-welded and X-rayed again. Permanent record is kept of every inch of welded seam. Figure 2 shows a vessel ready for shipment, coming out of the normalizing oven.

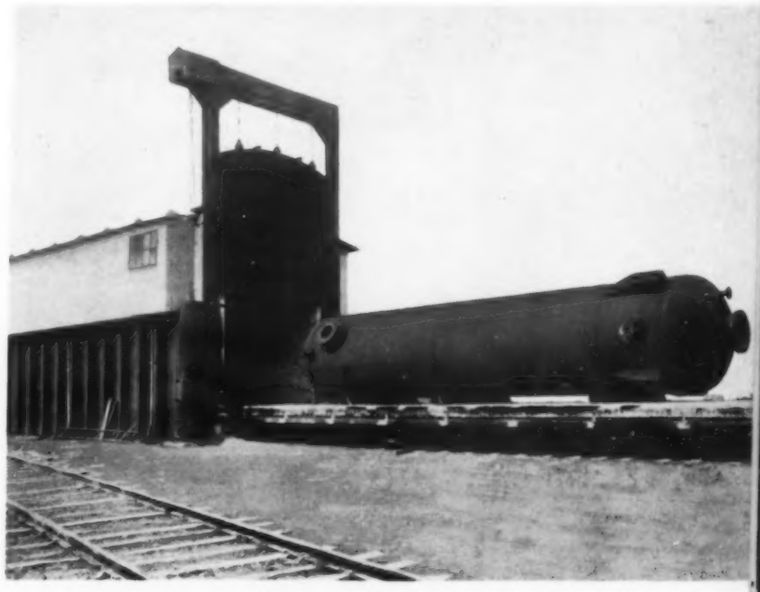
The test plates are the first to be X-rayed. They are then removed and while the vessel itself is being examined these samples are stress-relieved in a small electric furnace under exactly the same conditions that will be applied to the entire vessel. These conditions are accurately controlled and recorded for duplication on the vessel. Physical tests are then made and the check tests of the seam are completed nearly as soon as the vessel is ready for the furnace. No case has yet been found where the physical tests fail to meet all the Code requirements.

The following average physical properties after stress-relieving at 1200° F. have been obtained on A.S.M.E. 5-1 Boiler Plate:

Ultimate tensile strength	65,000 lb. per sq. inch.
Yield Point	54,000 lb. per sq. inch.
Elongation, 0.505 specimen	31% in 2 inch.
Specific gravity	7.825
Impact (Charpy)	33 ft.-lb.

After X-ray, the complete shell is placed in the gas-fired furnace to stress-relieve the finished vessels. The furnace is located close to the welding operations, as no time can be lost when the heat of the automatic welding mounts up from five to six hours. Strain-relief annealing consists of heating to 1200° F. and maintaining this temperature for one hour per inch of

FIGURE 2—Completed vessel ready for shipment after X-ray and testing.



maximum plate thickness, then cooling to 500° F. in the furnace. The rate of increase and decrease in temperature is three hours to raise from room temperature to 1200° F. and five hours to cool 500° F.

Hand welding of fittings is also done with A.C. The work is positioned for this operation.

Automatic welding has proved so satisfactory that in every case in which it is possible to do so, hand welding has been eliminated.

Experience of pressure vessel manufacturers is that the A.C. automatic given them somewhat greater net welding speeds than could be obtained with D.C., and fewer defects to be chipped out.

D. SPECIAL USES OF A.C. WELDING

1. Series Arcs

Two or more arcs in series are quite spectacular from a melting rate standpoint and is often used in very heavy welding or casting fitting sometimes with one or more filler rods or other filler material meltings in with the double arc. A.C. because it melts evenly each electrode can be used for a double electrode made like an inverted Jaclochoff candle and the current goes down one rod through the arc into the puddle and up out of the common puddle into the arc of the other electrode. This scheme can be used on two phase and on three phase delta on grounded neutral as in its parent the polyphase electric furnace. The extra heat of this arc welding and the warping of the carbon arc method comes back into the picture. The quick get away weld of the metallic arc is the secret of its success over the older carbon arc.

Very often the double A.C. arc can be used to advantage in emergencies by putting two men at work from one machine in series, each being a ground for the other. The welding apparatus is not overloaded; in fact the power factor is so improved as to lessen the load losses on the apparatus and the efficiency is increased but of course twice the power is drawn from the line less the decreased losses. The two men need not be working on the same piece if the different work is con-

Table B **AUTOMATIC A.C. ARC WELDING** **Typical Welding Data**

Plate Thickness Inches	Description of Passes	Pass No.	Electrode Diameter Inches	Welding Current Amp.	Arc Voltage	Approx. Welding Speed Inches Per Min.	Elec. Consumption Lbs. Per Min.	Oscillation	
								Approx. Amplitude Inches	Frequency Osc. Min.
	Bottom of Groove	1	5/32	130	25	7½–8	.045	None	
		2	3/16	175	28	6	.074	None	
		3	3/16	175	28	5	.074	1/32	
½″		4	¼	275	30	4¼	.13	1/16	
	Hand Backing Beads	5	¼	275	30	4½	.13	1/16	
		6	¼	275	30	4½	.13	3/32	
	Bottom of Groove	1	3/16	175	28	7½–8	.074	None	
		2	3/16	175	28	6	.074	None	
		3	¼	380	38	5	.20	1/32	36
		4	¼	380	38	4¾	.20	1/16	36
		5	¼	380	28	4½	.20	3/32	36
		6	¼	380	38	4½	.20	1/8	36
		7	¼	380	38	4	.20	5/32	36
1½″		8	¼	380	38	3½	.20	3/16	36
		9	¼	380	38	3½	.20	7/32	36
		10	¼	380	38	3½	.20	¼	36
		11	¼	380	38	3¼	.20	9/32	36
		12	¼	380	38	3¼	.20	5/16	36
		13	¼	380	38	3	.20	11/32	36
Hand	Hand Backing Beads	14	¼	380	38	3	.20	1/16	
		15	¼	380	38	3	.20	3/32	
	Beads	16	¼	380	38	3	.16	1/8	

nected by a common ground or a wire between them. When one man stops work he must "ground" his handle if the other is to continue. Two buddies or one man with a rod in each hand operate the best.

2. GAS BATHED ARC

The original name of shielded arc was applied to the welding in a gas; generally inert of a single metallic electrode bare or covered and also experiments with non-burning electrodes in an envelope of gas were originally called the shielded arc. These efforts to weld in a protective gas are still being tried and revived again and again but so far the special case of tungsten double electrode in hydrogen or illuminating gas is the only industrial use—double electrode and series electrode burning arcs in hydrocarbon gases seems to lend itself to some good use ultimately because the arc ignites the hydrogen which burns keeping the air away from the arc and melted metal and the carbon enters the nascent deposited metal increasing its strength. Arc welded metal with desirable constituents such as carbon are often burned out but if applied after melting as from a gas or covering will enter into the deposit. The gas arcs are hindered by the costs of both arc and gas.

3. Semi-Flash Arc

The Semi-Flash Arc is very popular in the automotive trade and consists of an A.C. current whose voltage is not sufficient to "hold" the arc but which starts or flashes on successive, generally rapid contacts depositing some metal at each flash. The popular electrode is pure nickel or a nickel alloy although soft irons are also used in the larger sizes. In welding defects in cast iron the quickness leaves no hard spots. Practically all cylinder boring machine plants are equipped with this device to correct defects in the machined surface as they appear most often without disturbing the machine tool set-up. In repair work it is used for the same purpose and for worn valve seats and various other uses some of its exponents becoming so enamored with the process as to use it on frames, cast iron boiler sections, radiators, etc. It is at present most popular in the middle west and vicinity of the automotive plants.

4. Hydrogen Flame Arc

The Hydrogen Flame Arc, called by one company the "Atomic" arc, is another exclusive A.C. product. Generally Tungsten electrodes are used bathed in an atmosphere of hydrogen; danger of explosion if the gas is not kept burning and the necessity of lighting it as it comes from the gas orifice.

The *best* metal in a sense of pureness is made by this process and it is very useful for work requiring ductility as in a diaphragm or other weld under live load or subweld under live load or subject to repeated deformation. Illuminating gas or other hydro-carbon can be used in place of pure hydrogen if carbon is desirable or permissible in the deposit.

Heavy work is impractical for the same reason as is the carbon arc, i.e. too much heat and because the "atomic" arc is more costly than either gas or arc welding. For thin work especially stainless or chrome or other alloys which would oxidize too readily it is indispensable. For edgewise work especially if three or more edges are to be joined, judicious use can make it pay for its increased cost in increased production. Its efficacy lies in the exclusion of air by the hydrogen.

5. Double Carbon Arc

The double carbon arc ofttimes called the Brazing Torch is still another popular A.C. use. Here a flame arc, exactly like an arc lamp projector with the carbons or praphites at an angle, are arranged to create a flame directed outward which is used like a gas torch to melt edges, add metal or melt filler rod as in gas welding. Generally edgewise or corner welding is best done with this process. The welding of steel edges with or without a filler rod in the main use because the heat is twice that of a single carbon arc which is already too hot for continued welding unless warping is not bothersome.

With the Electric Arc brazing methods the grain structure changes of high arc temperatures in the parent metal are avoided and with the proper selection of brazing material very often good results can be obtained. The arc advantage here over gas is its lesser cost and no bottles.

Using the double carbon as a preheater or frame straightener is very popular and strain relieving can be accomplished by it neater and quicker and more accurate than with a gas torch. As an idea of its speed and concentration of heating this arc can be drawn across a $\frac{1}{2}''$ plate leaving a red hot streak along which the plate can be bent accurately. It can be used as is a gas torch for welding aluminum and other non-ferrous alloys but as a brazing tool it is the most useful. Any of the regular soldering or brazing alloys such as silver or cadium or any brazing spelter can be used with it on steel or non-ferrous metals. The ordinary flux is used and the same methods as in gas or furnace brazing.

A little brother of this torch is the arc soldering iron where a single arc generally carbon with about five amperes keeps a copper tip hot for general soldering. The arc is generally started by snapping the carbon against the copper tip and the arc is extinguished by interrupting current supply.

6. Cast Iron and Manganese

The A.C. arc is satisfactory for casting welding, especially for cast iron and manganese welding. I have no explanation to offer for this phenomenon except perhaps the greater puddling action with the alternating current arc. It is a fact that with or without special electrodes and special coverings and enclosures both cast and manganese weld better, smoother and with less cracking with the A.C. arc. Even bare wire manganese shows this attribute of A.C.

This leads to extensive welding with heavy and immovable castings and track and special worker fixed in place and this chapter will not deal with these applications.

7. High Frequency A.C.

The higher the frequency the more easily the arc is sustainable and motor generators driven at high speed (3600 RPM) are used to give 200 cycles for welding using the M.G. as a frequency changer with proper

(*Please turn to page 67*)

LOW VOLTAGE

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Presented before the A. I. & S. E. Annual Convention, Chicago, Illinois, September 28, 29, 30, October 1, 1937

▲ IN the early days of the electrification of the steel industry, not much study was necessary on the low voltage distribution system, due to the small amount of motorized auxiliaries, and not much study was put on it; as anyone who is familiar with the early industrial installation will have to admit, most of the time and money was spent on the layout and arrangement of the mill equipment, while the necessary power lines were left to the mill electrician to be installed in any manner he could get them up and with the least possible cost and time.

However, today in a modern electrified steel mill with the total connected H.P. in auxiliary equipment sometimes exceeding the main drive H. P. capacity and with the additional responsibility of maintaining continuity of service on auxiliary drives equally as important as that of main drive equipment, in the interest of true economy—which involves over-all yearly cost for the entire plant, field charges plus operating expense —the steel plant management should realize that well planned and installed low voltage distribution systems pay dividends and that, by trying to save money on an original installation, by installation of inadequate units, using cheap cable, labor, and material that this only raises the over-all plant operating cost, due to the many ills that come about from a poorly planned and installed distribution system—such as circuit outages, excessive voltage drop, curtailment of production due to breakdown, by not having an adequate stand by unit, or by not having arranged for tie lines between distributing points.

No doubt the above facts have been brought forcibly to the attention of many a steel plant electrical superintendent by his daily delay reports and his operation cost sheet.

SYSTEM STUDY

The first step in any such study is a careful survey and analysis of the load requirements. The object of the load study is to determine the magnitude and also the distribution of load throughout the plant.

Some differences in economy are due to the physical shape of a plant, quite a few of our steel plants have grown up along river banks, and are composed of very long and narrow areas which makes centralization of low voltage distribution and location of substations more difficult than for a more compact area.

Not having any previous records of existing plants, with complete meter readings, etc., it is necessary to resort to the installed horsepower. Having arrived at the total horsepower capacity for each building or section, a factor must be applied to obtain the equivalent average load at the station bus with the plant operating at full production. This factor will depend on the diversity of utilization or, more precisely, on how much of the installed power will operate simultaneously. This factor is an extremely important one as its correct evaluation can contribute more than any other to determine the necessary capacity of conversion equipment to install, and the correct size of feeder circuits for distribution efficiency.

To evaluate this "Demand" or "Simultaneity" factor very closely is very difficult and requires experience and familiarity with the individual processes which make up total in steel mill production.

It is always very desirable to establish this factor for the particular type of plant under consideration by actual average load measurements at the existing station. The chart should cover at least a full day and a time when the plant is operating at maximum production capacity in all departments. Allowance to the factor obtained from the chart readings would have to be made to offset subnormal production and to allow for future growth of the plant. Also if readings are taken in summer, allowance should be made for winter load conditions.

From the above statements you can readily see the value and help to any steel mill electrical man, by discussion from the different steel mill plants as to the actual demand factor required for the different types of mills, for their auxiliary drives.

In general in laying out the distribution system for a steel mill, several schemes should be considered. As there is such a wide variety of products covered by steel mill installations, it is not feasible to set up a hard and fast rule to follow as each different plant or mill constitutes a problem in itself.

To make an economic study, the following are some of the things to be done and considered:

A. DETERMINATION OF LOADS AND LOAD CENTERS

1. Survey and analysis of demand requirements.
2. Large or small conversion units.
3. Standardization on size of unit.
4. Spare units or portable substations.
5. Availability of station sites.

Systems in STEEL PLANTS

D. C. NELSON

B. CHARACTERIZATION OF SYSTEMS

1. Automatic.
2. Semi-automatic.
3. Manual.
4. Regulation.
5. Consideration of changes and additions.
6. Efficiency of equipment under requirements.
7. Power factor relation.

C. TYPE OF EQUIPMENT

1. Machines:
   a. Synchronous Motor Generators.
   b. Induction Motor Generators.
   c. Synchronous Converters.
   d. Mercury Arc Rectifiers.

In choosing the kind of machine, consider:

Installed cost.
Space requirements.
Efficiency.
Power factor conditions.
Parallel operations.
Safety features.
Reliability.
Character and amount of maintenance.

2. Transformers—Consideration should be given to:
   a. Installed cost.
   b. Space requirements—Single or three-phase.
   c. Efficiency.
   d. Fire hazard—Location—Type of cooling.
   e. Advantages of connections.
   f. Advantages of installing 2 single-phase open-delta connections of larger size to give approximate same capacity as 3 single-phase connected in closed delta.
   g. Standardization in size and characteristics for interchangeability purposes, spare units, and parallel operation.

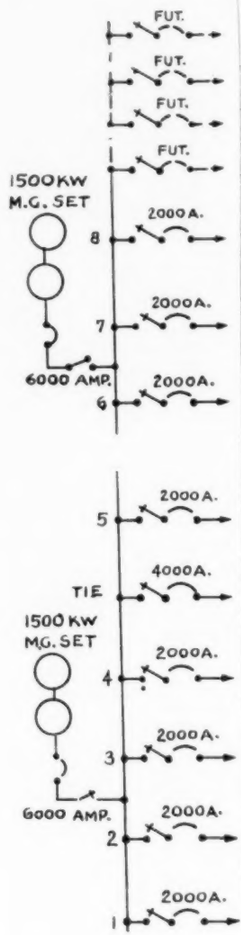
D. FEEDER CIRCUITS

1. A-C Feeders:
   a. Manual, Magnetic, or Automatic.
   b. Safety enclosed truck type or open type fixed units.
   c. Metering.
   d. Circuit breaker—2 or 3 pole.
   e. Knife switch—any—2 or 3 pole.
   f. Size—Single or multiple feeds.
   g. Standardization.
   h. Safety features.
2. D-C Feeders:
   a. Manual, Magnetic, or Automatic.
   b. Safety enclosed truck type or open type fixed units.
   c. Metering.
   d. Circuit breaker—1 or 2 pole.
   e. Knife switches—any—1 or 2 pole.
   f. Size—Single or multiple feeds.
   g. Standardization.
   h. Safety features.
3. Feeder Circuits:
   a. Overhead or underground.
   b. Bus or cable.
   c. Arranged for ease in isolating faults, least interference from other circuits, building extensions, and accessibility for repairs and extensions.
   d. Protection against mill operating hazards.
   e. Ample capacity for distribution of loads and with margin of safety for additions of new loads or redistribution of loads.
   f. Distribution efficiency—load voltage conditions necessary.
   g. Interconnection of feeders.
   h. Completely sectionalized—One side of system solidly grounded.

E. DECISION BASED ON COMBINED STUDY OF PRACTICAL CONSIDERATIONS AND TRUE ECONOMY

On the following seven pages will be found single line diagrams of recent hot and cold mill installations:

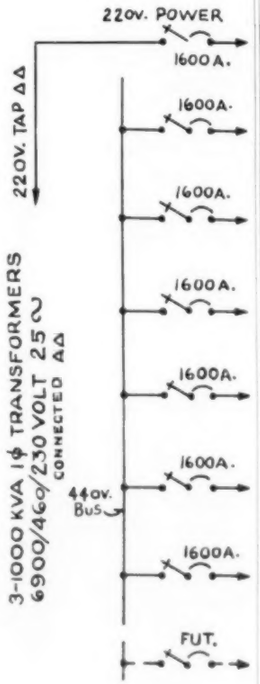
SKETCH A—HOT MILL 250 VOLT D.C. DISTRIBUTION



	No. of Motors	Total H.P.	Total Amp.	Estimated Load Amps. Peak	Estimated Load Amps. Aver.	Actual Load Amps. Peak	Actual Load Amps. Aver.	Design Data: Cable Size and No.	Design Data: Arr'g't.	Design Data: Lgth. (One Way)	Design Data: Volts Drop (Aver. Load)	Service	Remarks
					1000								
					1000								
					1000								
					1000								
8	25	921	3803		1000			4 1000M C.M. T.B.W.P.	•••• + —	500 ft.	5.3	Hot Bed Transfer—Plate Finishing 96″ x 5/16″ Shearing Unit—Excitation Control For Flying Shear and Runout Tables	230 V. Motors Mill Rating (1 Hr.)
7	36	1434	5271		1500			4 1000M C.M. T.B.W.P.	4½″ •••• + —	375 ft.	6.0	Side Guards—Screwdowns 93″ Leveller and Shear Conveyor Tables	230 V. Motors Mill Rating (1 Hr.)
6	30	1400	5130		1500			4 1000M C.M. T.B.W.P.	•••• + —	600 ft.	9.6	Plate Finishing Equip. D.C. Control Excitation on A.C. Panels	
5	83	2580	9673		2000			4 1000M C.M. T.B.W.P.	•••• + —	725 ft.	15.4	Trimmer-Leveller—Cutup Units—55″ Sheet Mill Aux.—Coil Conveyor—Scrubber Continuous Pickler Aux	230 V. Motors Continuous — Mill (1 Hr.) Ratings
TIE								SEE SKETCH "F"				To Cold Mill To Central Power House	
4	23	1321	4815		1500			4 1000M C.M. T.B.W.P.	•••• + —	200 ft.	3.2	Edging Rolls Screwdowns Side Guards	230 V. Motors Mill Rating (1 Hr.)
3		445 Kw.	1500		1000			4 1500M C.M. R.C.	4–3″ Cond. 0000 + —	65 ft.	0.46	Emergency Excitation 300 Kw. Main Exciter, 1–30 Kw. 1–15 Kw. CEMF Sets 100 Kw. Dyn. Braking Rough Mill Motors	
2	44	1504	5523		1500			4 1000M C.M. T.B.W.P.	•••• + —	750 ft.	12.0	Slab Pusher—Screwdowns Furnace Pushers—Furnace Tables Roll Shop	230 V. Motors Mill Rating (1 Hr.)
1	62	2783	10663		2000			4 1000M C.M. T.B.W.P.	•••• + —	Aver. 500 ft.	10.6	Crane Circuit 15 Cranes	230 V. Motors Crane Rating (½ Hr.)
TOTAL	303	11943			16000								

Assuming 75% Normal Operation of Plant. .75 x 16,000 = 12,000A. Full Load on Machines. Machines Rated 125% O. L. for 2 Hrs. 200% for 1 Min.

SKETCH B—HOT MILL 220 & 440 VOLT A.C. DISTRIBUTION



No. of Motors	Total H.P.	Total Amp.	Estimated Load Amps. Peak	Estimated Load Amps. Aver.	Actual Load Amps. Peak	Actual Load Amps. Aver.	Design Data: Cable Size and No.	Design Data: Arr'g't.	Design Data: Lgth.	Design Data: Volts Drop (Aver. Load)	Service	Remarks
464	332	2350		800			6 1000M C.M. T.B.W.P.	•••• ••••	250 ft.	6.02	Drinking Fountains—Solenoids—Thrustors—Heaters —Hot Runout Tables—Table "D" Regular (212 Hp.—1442 Amp. for Other Runout Tables)— Emergency Only	
193	2307	3053		1600			3 1000M C.M. T.B.W.P.	••••	600 ft.	43.7	Aux. Power Included in Current Total are— No. 203—3 Kw. Motor RM. Heaters 1 φ / No. 704—24 Kw. Oil Heater 1 φ } 61 Amp.	
12	374	462 Fut.		200 600			3 No. 410 R.C.	In Cond.	200 ft.	14.2	Motor Room Fans—Heaters—Filters Included in Current Total Are— Motor and Generator Heaters 1 φ —457 Amp.	3 Circuits from this Panel Design Data Estimated for One Circuit
	616.5 Kw.	810		600			3 1000M C.M. T.B.W.P.	••••	500 ft.	13.8	Lighting—21-37.5 Kva. 1 φ 460/230/115 V. Transformers { "A" Phase—830 Amp. "B" Phase—795 Amp. "C" Phase—805 Amp.	
1	580	570		400			3 1000M R.C.	Open Wiring ••••	200 ft.	3.65	Main Exciter in Motor Room .8 P.F.—435 Kva.	
6	944	1013		600			3 1000M C.M. T.B.W.P.	•••• 4½"	540 ft.	14.9	2 Skin Pass Mills—96" and 55" 300 Hp. Main Drive—Aux. Drives	
							4 1000M C.M. R.C.	Wood Block 1¾"	700 ft.	24.3	Welder—A.C. φ 440 V. 1 Pickling Line Welder / 2-700 Kva. 1 φ Transf. } 3180 Amps.	
676	4537			4800								

TOTAL

The Reactive Drop was Calculated by the Formula Given in the "Standard Handbook for Electrical Engineers" on Page No. 930—Edition 1922.

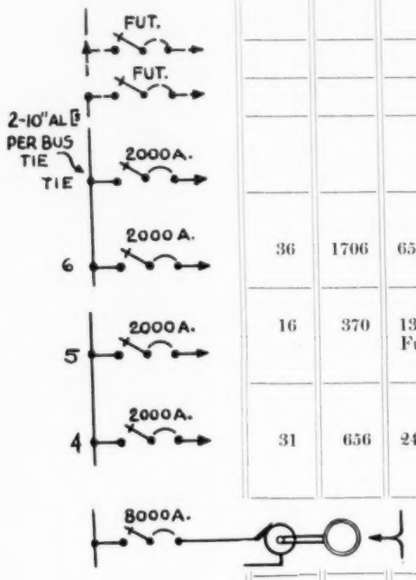
$x = 2\pi f \left(80 + 741 \log \frac{D}{r}\right) 10^{-6}$ Ohms per Mile.

Total Connected Kva. Approx. 5000.

Cap. 3—1,000 Kva. Δ Δ Transformers 3000.

Ratio $\frac{3000}{5000} = 60\%$.

SKETCH C—COLD MILL 250 VOLT D.C. DISTRIBUTION

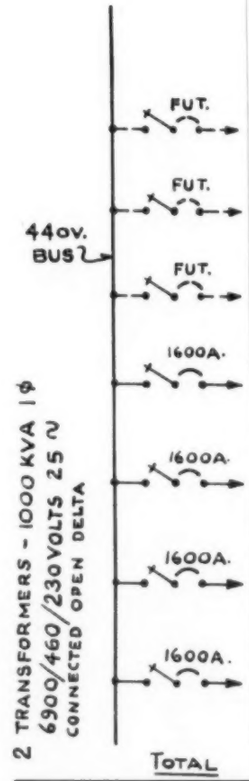


No. of Motors	Total H.P.	Total Amp.	Estimated Load Amps. Peak	Estimated Load Amps. Aver.	Actual Load Amps. Peak	Actual Load Amps. Aver.	Design Data: Cable Size and No.	Design Data: Arr'g't.	Design Data: Aver. Lgth. (One Way)	Design Data: Volts Drop (Aver. Load)	Service	Remarks
				1100								
				1100								
							SEE SKETCH "F"				Tie Line to Hot Mill D.C. Bus—4—1,000M. C.M.W.P. Wire per Leg	
36	1706	6552		1600			2 1000M C.M. T.B.W.P.	•••• + —	500 ft.	17.0	9 Cranes	230 V. Motors—Crane Rating (½ Hr.)
16	370	1376 Fut.		600 200			4 1000M C.M. T.B.W.P.	•••• + —	350 ft.	3.0	93" Single Stand Mills	230 V. Motors—Mill Rating (1 Hr.)
31	656	2423		1000			4 1000M C.M. T.B.W.P.	•••• + —	1000 ft.	10.6	Roll Grinders, 55" Mill, 76" Trimmer and 93" Sheet Leveller	230 V. Motors—Continuous Rating
							2000 Kw. D.C. Gen. 250 V. Comp. Wound—375 R.P.M. 2800 Kva. Synch. Motor 0.8 P.F. 6600 V. 3 ϕ 25 ~ Reactor Starting					
16	650	2382		1000			4 1000M C.M. T.B.W.P.	•••• + —	500 ft.	5.4	93" Trimmer and Upender Galvanizing Equip. Anneal. Fce. Charging Car	230 V. Motors—Continuous Rating
24	825	3059		1400			4 1000M C.M. T.B.W.P.	•••• + —	400 ft.	5.95	93" Tandem Mill 54" Tandem Mill	230 V. Motors—Mill Rating (1 Hr.)
1	500 (300 Kw.)	1800 (1200)		1800			6–2000M CM–RC	000000 + — 6–3½" Cond	50 ft.	4.7	93" Sheet Mill Main Drive Emergency Excitation	250 V. Motor—Continuous Rating
							3"–1–46 Al. Chan'l	‖ ‖ + —	400 ft.			
				2200			SEE SKETCH "F"				Tie Line—No. 1 and No. 2 Sub-Stations	
124	4707			12000								

NOTE: Assuming 75% Normal Operation of Plant, .75 x 12000 = 8000A. Full Load on Machine.
Machine Rating Good for 150% O.L. for 2 Hrs. or 12000A. 200% O.L. for 1 Min. or 16000A.

NOTE: Assuming 75% Normal Operation of Plant, .75 x 12000 = 8000A. Full Load on Machine.
Machine Rating Good for 150% O.L. for 2 Hrs. or 12000A. 200% O.L. for 1 Min. or 16000A.

SKETCH D—COLD MILL 440 VOLT A.C. DISTRIBUTION



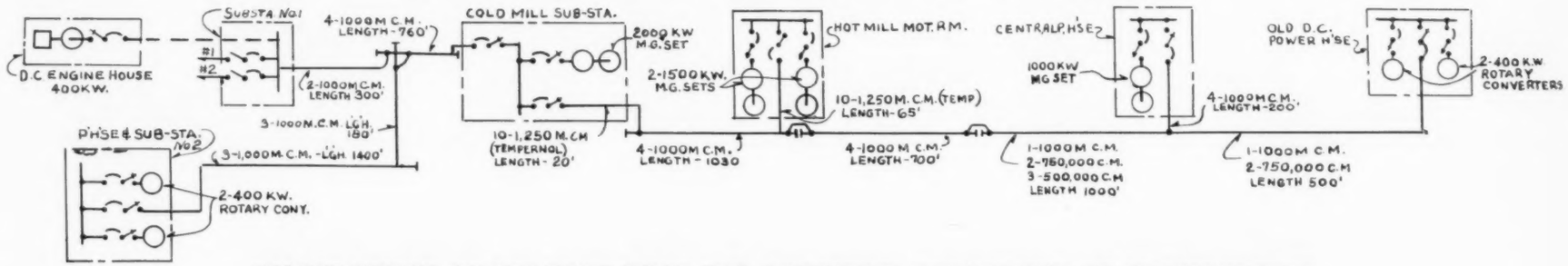
No. of Motors	Total H.P.	Total Amp.	Estimated Load Amps. Peak	Estimated Load Amps. Aver.	Actual Load Amps. Peak	Actual Load Amps. Aver.	Design Data: Cable Size and No.	Design Data: Arr'g't.	Design Data: Lgth.	Design Data: Volts Drop (Aver. Load)	Service	Remarks
204	1314	1807		1000			3 1000M C.M.	••••	400 ft.	18.4	Auxiliary Motors Included in Current Total Are: 1—12.5 Kw. Furnace, 2—Water Coolers } 1 ϕ 35 Amp.	LC—Where Cable changes to 600,000
24	526	682		500					200 ft.	9.0	Fans—Filters—Heaters Included in Current Total Are: Motor Room Heaters—1 ϕ 204 Amp.	5 Circuits from this Panel Design Data Estimated for One Circuit
		687 (aver.)		600			3 1000M C.M. W.P.	•••• 4½"	500 ft.	13.7	Lighting—19–37.5 Kva. 1ϕ 460/230/115 V. Transformers { Phase A—681 Amps. Phase B—656 Amps. Phase C—725 Amps.	
1	580	590		590			3 1000M C.M. W.P.	••••	13.5 ft.	3.7	435 Kva. Main Exciter	
229	2420			2690								

The Reactive Drop was Calculated by the Formula Given in the "Standard Handbook for Electrical Engineers" on Page No. 930—Edition 1922

$$x = 2\pi f \left(80 + 741 \log \frac{D}{r}\right) 10^{-6} \text{ Ohms per Mile}$$

Total Connected Kva. 3ϕ 2850
Cap. 2 V. Trans. 58% 3000 = 1740
Ratio $\frac{1740}{2850}$ = Approx. 60%

SKETCH E—250 VOLT D.C. TIE FEEDERS



CALCULATIONS OF VOLTAGE DROP FOR DIFFERENT CONDITIONS OF TRANSMISSION.

1—SUPPLYING 1000 KW. AT 250 VOLT D.C. FROM HOT MILL SUB-STATION TO CENTRAL POWER HOUSE

C = 4000 AMPS. L = 1700 FT. $R = \frac{0.0106}{4} \times 1.7 = 0.0045$ OHMS DROP = 4000 x 0.0045 x 2 = 36 VOLTS = 14.4% (AT 25° C.)

2—SUPPLYING 1000 KW. AT 250 VOLT D.C. FROM HOT MILL TO COLD MILL SUB-STATION

C = 4000 AMPS. L = 1030 FT. $R = \frac{0.0106}{4} \times 1.03 = 0.00273$ OHMS DROP = 4000 x 0.00273 x 2 = 21.8 VOLTS = 8.7%

3—SUPPLYING FROM COLD MILL SUB-STATION—300 KW. TO NO. 1 AND 500 KW. TO NO. 2 SUB-STATION

CK = 1200 AMPS. L = 760 FT. TO BRANCH POINT $R = \frac{0.0106}{4} \times 0.76 = 0.00202$ OHMS

CS = 2000 AMPS. LK = 300 FT. TO NO. 1 $R = \frac{0.0106}{2} \times 0.3 = 0.00159$ OHMS

LS = 1580 FT. TO NO. 2 $R = \frac{0.0106}{3} \times 1.58 = 0.00563$ OHMS

DROP TO BRANCH POINT = (2000 + 1200) x 0.00202 x 2 = 12.9 VOLTS

DROP TO NO. 1 = 1200 x 0.00159 x 2 = 3.8 VOLTS

DROP TO NO. 2 = 2000 x 0.00563 x 2 = 22.5 VOLTS

TOTAL DROP TO NO. 1—16.7 VOLTS = 6.7%—TO NO. 2 35.4 VOLTS = 14.1%

4—SUPPLYING 800 KW. TO NO. 2 FROM COLD MILL SUB-STATION ALONE

C = 3200 AMPS. R = (0.00202 + 0.00563) x 2 DROP = 3200 x 0.0153 = 49.0 VOLTS = 19.6%

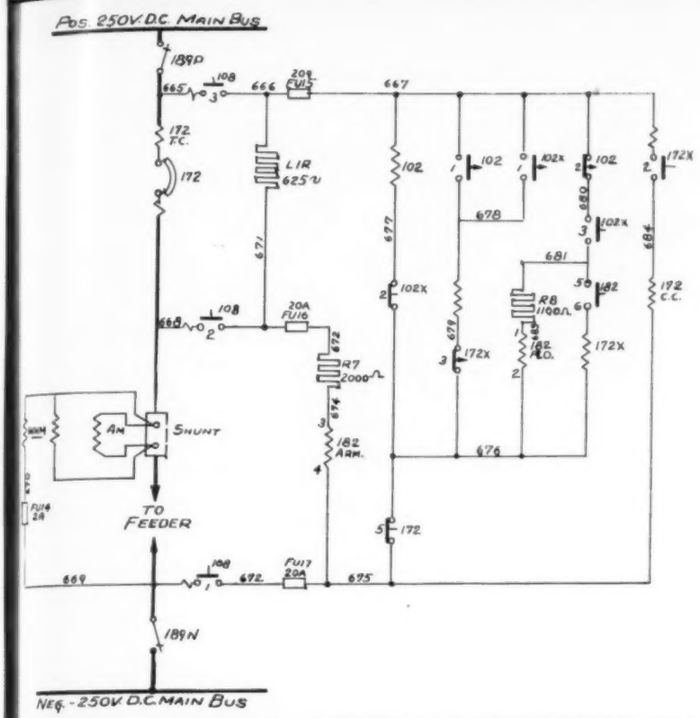
5—SUPPLYING 400 KW. FROM CENTRAL POWER HOUSE TO NO. 2 S.S. IN EMERGENCY

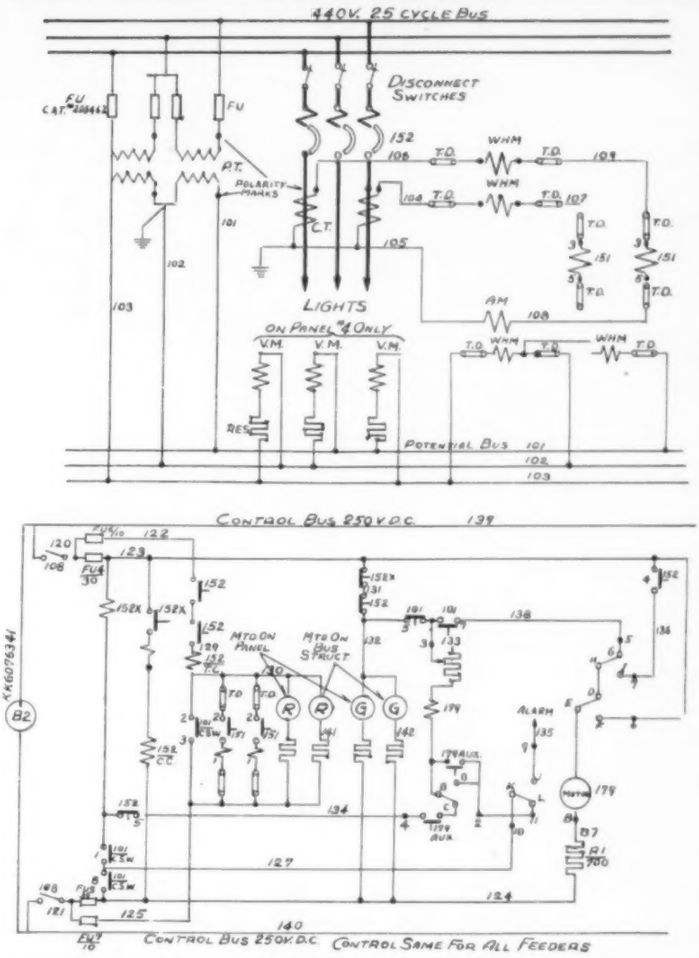
C = 1600 AMPS. R = 0.0045 + 0.00273 + 0.00202 + 0.00563 DROP = 1600 + 0.0149 x 2 = 47.8 VOLTS = 19.1%

6—SUPPLYING 600 KW. FROM OLD D.C. POWER HOUSE TO CENTRAL POWER STATION

C = 2400 AMPS. L = 500 FT. $R = \frac{0.0142}{2} \times 0.5 = 0.00355$ OHMS DROP = 2400 x 0.00355 = 8.5 VOLTS = 3.4%

R = 0.0106 OHMS IS THE RESISTANCE OF 1,000,000 CM CABLE PER 1000 FT.

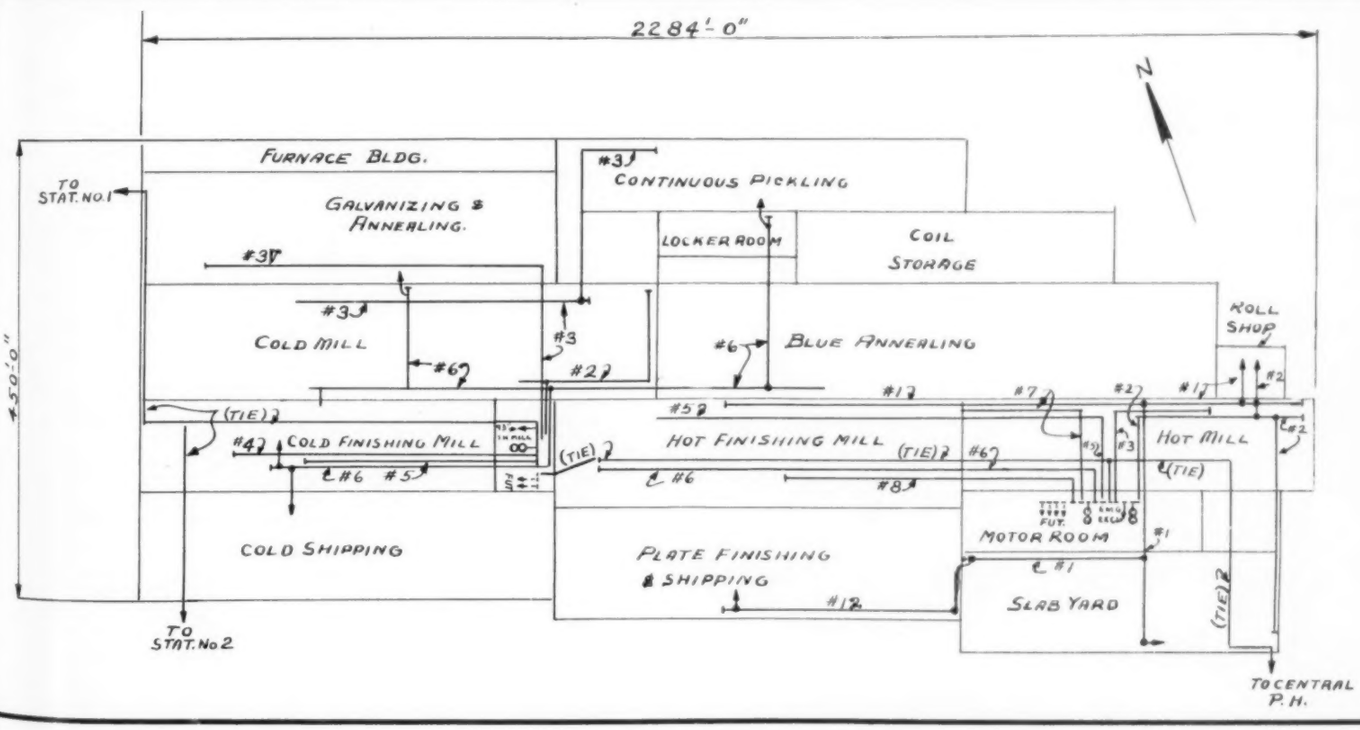


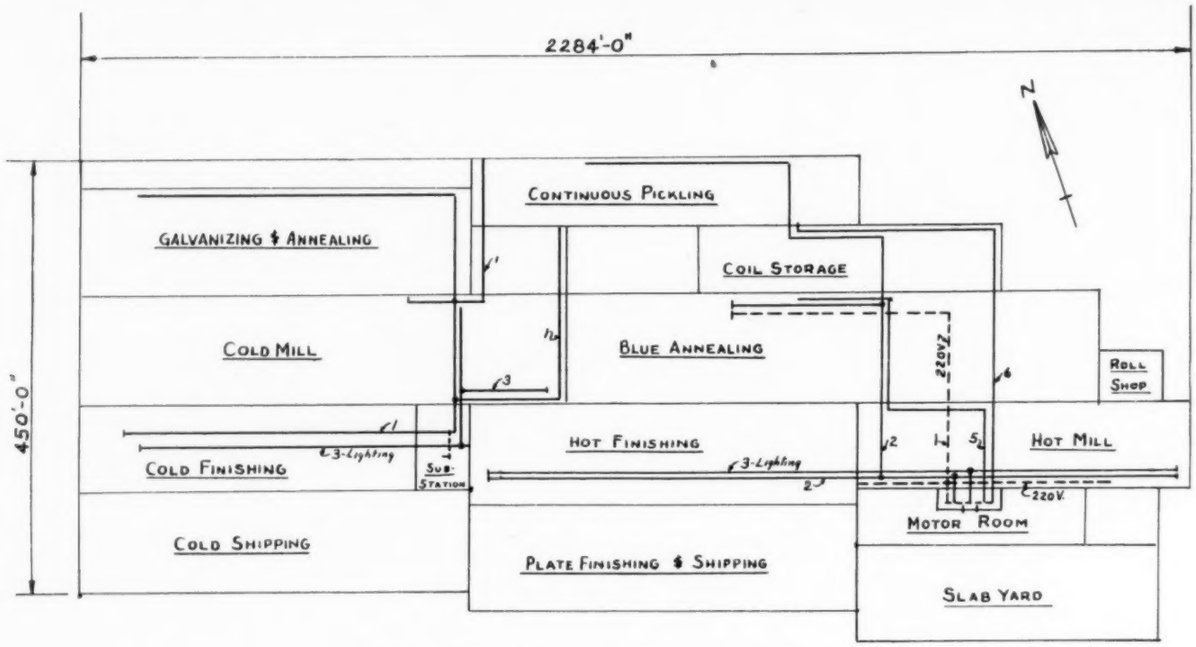


(Above) **SKETCH F—250 Volt D.C. Feeders Elementary Diagram**

(Right) **SKETCH G—440 Volt A.C. Feeders Elementary Diagram**

(Below) **SKETCH H—Key Plan 250 Volt D.C. Distribution**





SKETCH I—Key Plan 440 Volt A.C. Distribution

DISCUSSION

PRESENTED BY

L. R. MILBURN, Electrical Engineer, Great Lakes Steel Corporation, Ecorse, Michigan.

F. R. BURT, Industrial Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

J. FARRINGTON, Electrical Superintendent, Wheeling Steel Corporation, Steubenville, Ohio.

T. E. HUGHES, Superintendent Electric Light and Power and Mechanical Departments, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

H. A. GLOVER, Electrical Engineer, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

L. R. MILBURN: I have had the pleasure of reading Mr. Nelson's paper and wish to thank Mr. Wiley, Managing Director of the Association of Iron and Steel Engineers, for the opportunity of discussing this paper and for the honor of being asked to discuss this paper.

I agree with Mr. Nelson that in the past very little thought has been given to the layout of the auxiliary power distribution systems in steel plants. I am familiar with one plant in which the distribution system grew as the machinery installation progressed over a number of years and at a recent date a slight study of the distribution system in this plant was made and the re-arranging of the power lines for the A.C. distribution resulted in the salvaging of several thousand pounds of copper and gave a better power distribution than the original layout.

I feel that the best way to discuss this paper of Mr. Nelson's is to outline some of the things that we have developed at the Great Lakes Steel Plant in connection with auxiliary power distribution; such as, running our distribution cables in the roof trusses and using as few soldered connections as possible, all of which make for ease of extension and neater looking construction.

We are fortunate in having our plant laid out in a rectangular system so that our substations, which are located in the main centers of load, are approximately on the four corners of a rectangular. From the accompanying illustration you may visualize the layout of our plant., which is approximately three-thousand feet square.

In the upper righthand corner is substation No. 1, containing two (2) 2,000 Kw., 250 Volt, M.G. sets. In the upper lefthand corner is substation No. 3, in which there is installed one (1) 2,000 Kw., M.G. set. In the right center is located substation No. 4, in which there are installed two (2) 2,000 Kw., 250 Volt, M.G. set, and in the left center is substation No. 5, containing one (1) 2,000 Kw., M.G. set. These four (4) substations are interconnected by sufficient tie lines to supply any part of our plant even though one or more M.G. sets may be out of service. This, as Mr. Nelson agrees, makes an ideal situation for 250 volt distribution. In the lower righthand corner is located

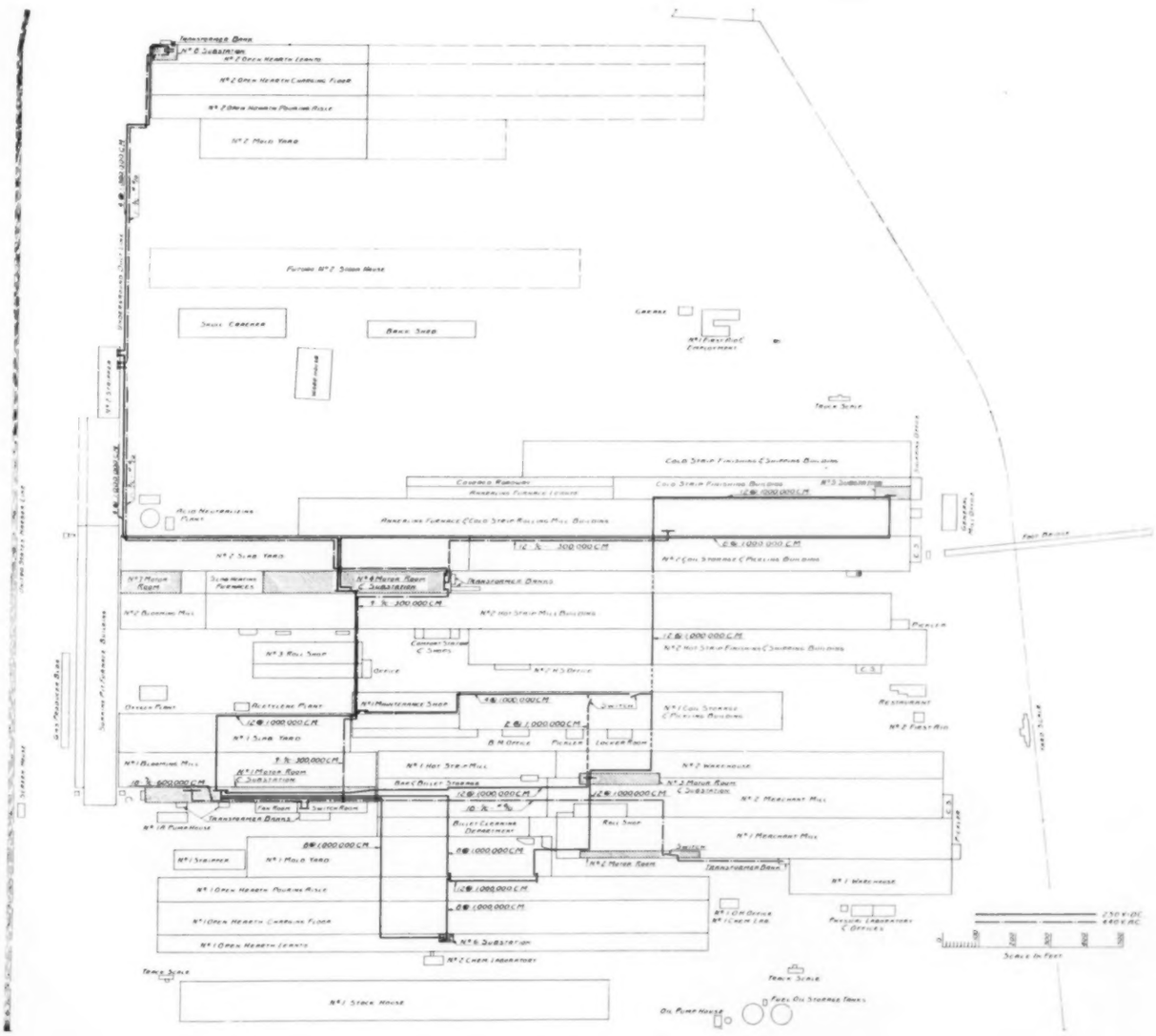
substation No. 8, which is in the new Open Hearth Department, to which we have no 250 Volt tie line. In this substation we have installed on alternate 6,600 Volt buses two (2) 2,000 Kw. M.G. sets, one to each high-tension bus. At this point we only have one (1) 1,000 Kw. generator on each synchronous motor. We have standardized on 2,000 Kw., M.G. sets, consisting of a 2,880 H.P., synchronous motor, 6,600 Volt, 3 Phase, 60 Cycle, with two (2) 1,000 Kw., 250 Volt, D.C. generators, and a 15 Kw. exciter, comprising an M.G. set.

As this Open Hearth grows, additional generators will be added to these two (2) sets. Eventually our future mills will probably be built in between the present mills and the new Open Hearths in such a way as to allow us to put in a 250 Volt tie between substations No. 4, No. 5 and No. 8. When this time comes, we will have a complete loop system, which is the ideal type of installation.

We have found from experience in our plant that a fairly accurate estimate of the load factor is about thirty per cent (30%) of the connected horsepower. We have also found in our plant that an estimate of a load center today might require a 500 Ampere feeder and yet, overnight practically this load center may so change due to the addition of more modern finishing equipment, to a point where a 2,000 Ampere feeder will not be ample to feed it. Under these conditions it is necessary to not only change the circuit breaker feeding this line, but it is also necessary to add additional cable in the roof trusses for this feeder.

We find at Great Lakes that it is much simpler to relieve the stresses on load centers by running open cables in the roof trusses as it is comparatively easy

Plan View of Electric Power Lines, Great Lakes Steel Corporation

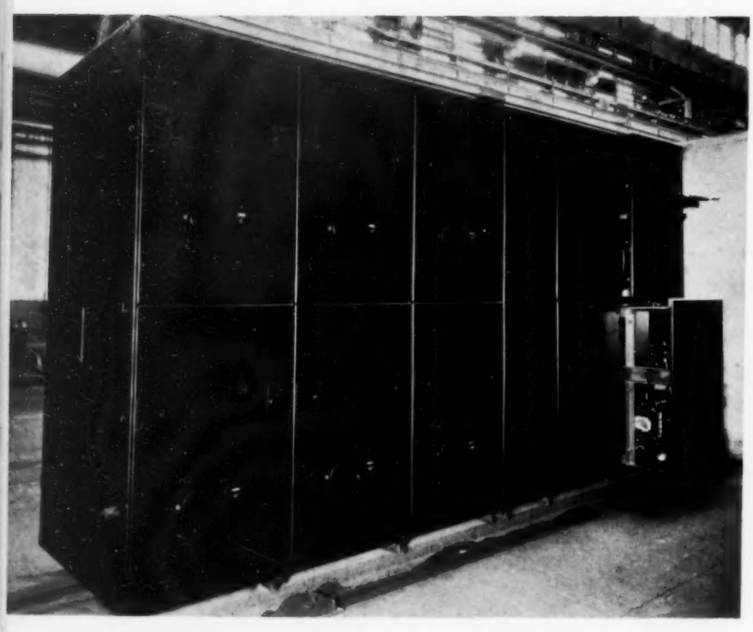


to add more cables to an existing line than it would be if these lines were underground and in conduits.

Soil conditions at the Great Lakes plant also forces us to keep as much of our distribution system overhead as possible. This soil is apparently made from decayed vegetation and seems to contain a light solution of acetic acid. We know of no other place in the country where this condition exists. This acid is slow to start disintegration action on the lead cables but after a period of two or three years seems to speed up quite remarkably and has caused a considerable amount of trouble in the Detroit area, not only to ourselves but to the local power company. It not only eats out the lead sheathe but also destroys the metal conduit and attacks the insulation of the cable itself. Therefore, we run in the ground only those conduits that are absolutely unavoidable and in these conduits the lead cable must be thoroughly coated with a fibrous grease at the rate of about one (1) pound of grease per ten (10′) feet of cable. We have experimented with numerous compounds to limit this corrosive action on metal conduits and lead, but so far only grease has been of any material help.

In regard to circuit breakers and feeder panels on the 250 Volt we find that the automatic reclosing, 4,000 Ampere, 250 Volt, D.C. feeder panel is the most economical to purchase and the best in regard to minimizing shut-downs due to overloads and other faults. Some of our substations are now equipped with manual circuit breakers but our new ones are all being equipped with automatic reclosing. We have not gone to automatic reclosing on the 440 Volt distribution system as yet. However, serious thought is being given to this feature and may be incorporated in later additions to our plant.

FIGURE 1—Illustration of a dead front metal enclosed feed assemblies. It consists of two feed circuits and incoming line compartment.

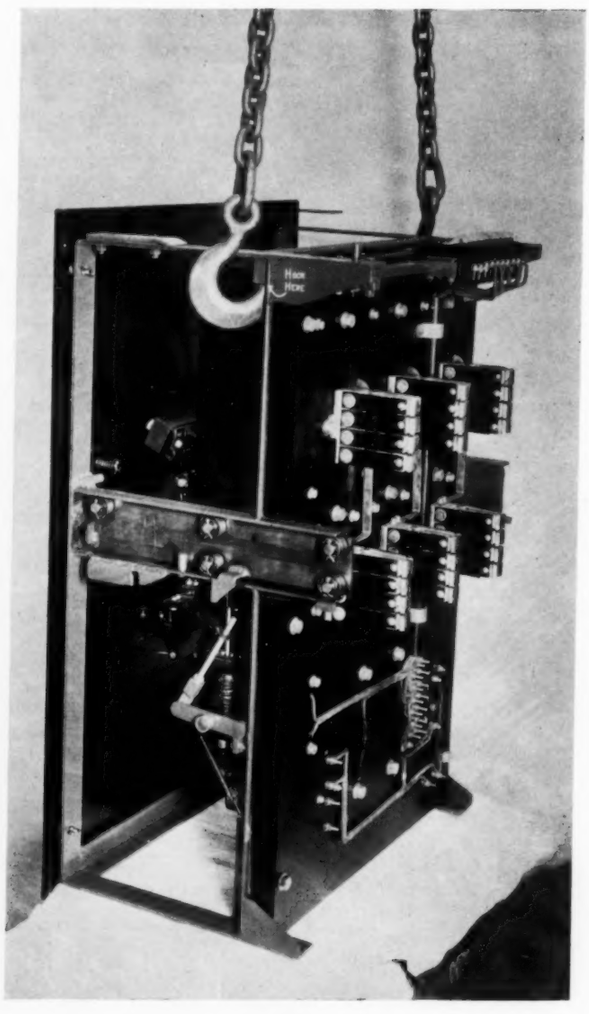


Any steel mill that will give sufficient thought to its auxiliary power distribution system is bound to save money in the long run due to the lack of shut-downs and due to the lack of scrap caused by unnecessary shut-downs when power fails.

F. R. BURT: Mr. Nelson has given a very complete outline of the various conditions which should be considered before laying out a low voltage distribution system, in order to obtain an installation which will be adequate for the original plant and which can easily be expanded to take care of future needs. In a general paper this is about as far as the subject can be discussed, since the actual layout of the low voltage system in any plant must be tailor-made for that plant and is not applicable to any other.

Knowing the arrangement of the plant, and location and capacity of apparatus to be supplied with power, it is not so difficult to lay out the original system, since sufficient information is available on peak loads and load factors of the various equipment to pre-determine

FIGURE 2—This shows one unit removed. The units are interlocked so they cannot be withdrawn unless the breaker is open.



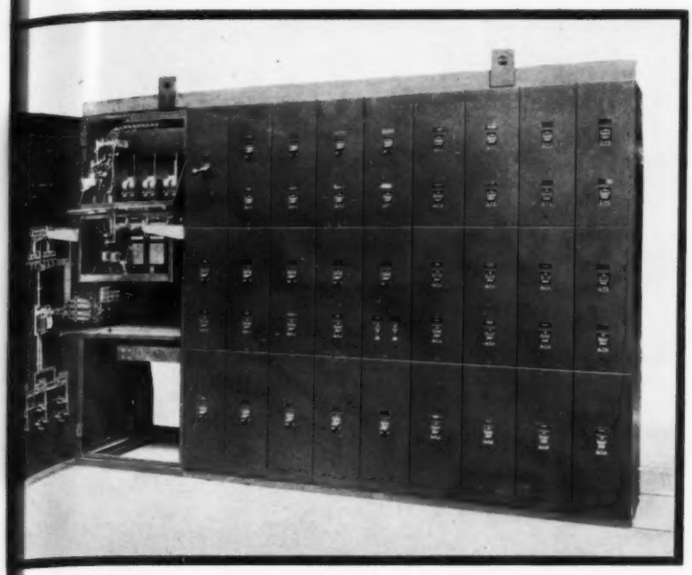


FIGURE 3—Is an assembly consisting of an enclosed group breaker and a number of dead front De-ian breakers

quite closely the characteristics of the various circuits. It is much more difficult to predict the direction, extent and character of future expansion, since changes in methods of production and in products themselves are continually being made.

The writer's chief interest is in the apparatus applicable on these distribution systems. Mr. Nelson has brought out the fact that it is not well to economize too greatly in selecting distribution apparatus. Several mills have gone so far as to install dead front, metal enclosed feeder assemblies, such as that shown in Figure No. 1. This assembly consists of two feeder circuits and incoming line compartment. Each feeder unit consists of a three pole carbon circuit breaker of the draw-out type. While admittedly higher in first cost than open panels this construction offers real advantages in the way of safety and quick replacement of defective units. The top right hand unit has the levering out device attached and is withdrawn to the "test" position. The bottom right hand unit is fully drawn out ready to be removed from the structure.

Figure No. 2 shows one unit removed. The units are interlocked so they cannot be withdrawn unless the breaker is open.

Figure No. 3 shows an assembly consisting of an enclosed group breaker and a number of dead front De-ion breakers. This apparatus was used in connecting to a loop system. With the group breaker omitted it would be applicable as a secondary distribution center on a branch system.

With the advent of the continuous hot strip mill has come the problem of distributing very large amounts of DC power to the motors driving the finishing end of the mill. The factors influencing the layout are the large currents to be carried, the high mechanical stresses in case of a short circuit and in most cases

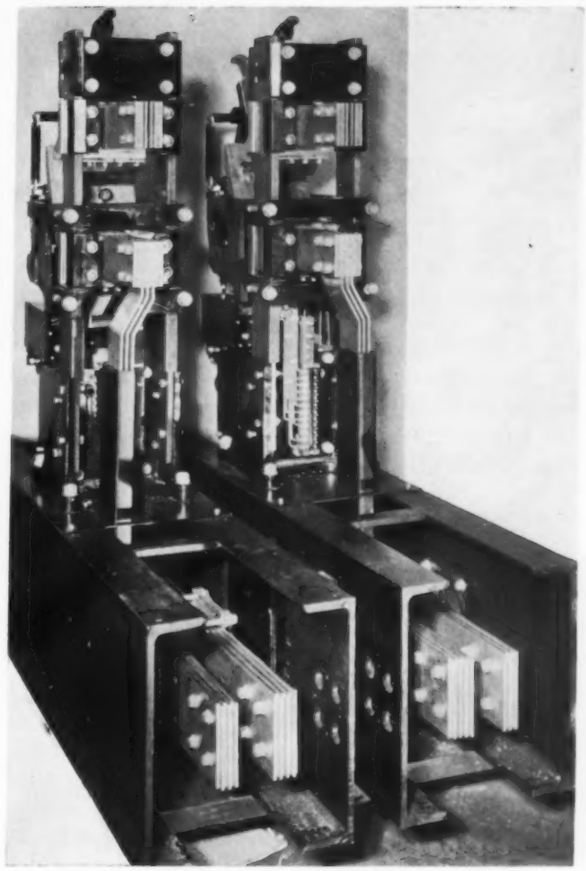


FIGURE 4—This shows a section of each bus with breakers mounted. The top of the enclosure is covered with steel plates.

restricted space. The bus and circuit breakers are usually located in the basement and in order to minimize short circuit stresses the positive and negative busses are separated as far as possible. The installation and bracing of this bus is a rather extensive field job.

On a recent continuous mill the direct current driving motors and the motor generator set supplying them were in a straight line, with a ventilating duct running underneath all the machines. Other space not being available in the basement it was decided to run the DC bus in this air tunnel. Each bus was enclosed in a channel structure approximately 18″ square and was fabricated in sections in the manufacturer's plant. The direct current circuit breakers were of the pedestal type mounted directly on top of the bus enclosure and underneath the respective machines which they served. The work in the field consisted of installing the sections on the floor of the tunnel—the positive bus on one side and the negative on the other—bolting the sections together and fabricating the connections between the upper studs of the breakers and the machine terminals. Figure No. 4 shows a section of each bus with breakers mounted. The top of the enclosure is covered with steel plates.

J. FARRINGTON: This subject is of vital interest to all electrical men operating steel mills, and Mr.

Nelson has given us a very comprehensive scheme for properly designing our low voltage systems.

Where a similar mill is installed, it will be of great aid in planning for a new mill, if tests can be made on the mill in operation

When a new mill of radical design or high speed is being planned, it is very essential that proper generators and feeders be installed to take care of the new conditions that are bound to arise.

Providing 75% of rated capacity of connected load in generators and feed lines seem to be about right, but we believe 80% and 85% should be allowed where the mill is of a continuous type and the ratio of productive to non-productive time is high.

Most mills eventually produce a greater tonnage than that for which they were designed, thus increasing the power required of the motors, feed lines and generators.

Temperature and analysis of the product rolled, materially increases the power requirements and should be carefully considered.

Spare ducts and pin space should be provided on all systems.

Sectionalized loop system is of great help when additional power is required, or a section of the system is in trouble, as that section can automatically be disconnected.

We still favor overload protection in both sides of the line and circuit breakers rather than fuses.

Where an installation is very important a supply power from two separate sources should be used.

We prefer overhead construction to underground cables, but where cable is used we recommend the conduit to be water-tight and open at each end for ventilation where they are above flood stage.

When cables are laid in places where the temperature of the ground may reach a dangerous condition, we pull a thermometer enclosed in a brass cartridge into a spare conduit to get the temperature.

Where cable terminals are below flood stage we believe they should be equipped with water-tight pot heads.

Cables should be selected with great care as to location, grounded or ungrounded, neutral-shielded or non-shielded, thickness of insulation, type of insulation, outside covering and distance between them as all these characteristics determine the size and length of life of the cables.

Lightning arresters should be used on each end of all outdoor cables, and where overhead lines join underground cables through pot heads.

I would like to ask Mr. Nelson if he has used any color code on the cables to designate the different voltages.

We wish to compliment Mr. Nelson on the distribution sketches, as they furnish all the information desired in a very compact form.

T. E. HUGHES: I was unfortunate in not having the pleasure of reading Mr. Nelson's paper before this meeting took place. I wish to congratulate Mr. Nelson on the excellent paper which he has presented and feel sure that everyone present received some benefit from a discussion of this subject. I don't know that there is really anything which I could add at this time to what has already been said. However, one of the boys from our plant, Mr. H. A. Glover, has prepared a few notes for discussion of this paper. I beg you to excuse me and to allow Mr. Glover to tell us what he has to say on the subject.

H. A. GLOVER: The absence of planned low voltage power distribution in steel mills is very evident in the older plants. Mr. Nelson is to be congratulated for his commendable paper bringing to our attention the planning necessary for a preliminary layout and outlining the factors to be considered in providing this power source. The article is quite timely, being in keeping with the continual expansion of steel working facilities and the increasing multitude of auxiliary drives.

In discussion of this phase of plant engineering there are many details of the various factors to be analyzed. I would like to bring to mind a few additional points which have a fundamental bearing on low voltage power distribution.

In calculating plant loads to determine equipment and feeder capacities, the question arises as to what load base this factor applies. Should the load factor of auxiliaries be based on the short time or peak rating of the motors, such as the one-hour mill rating, or one-half hour crane rating, or should the calculation be based on the continuous rating of the machine? Certain plants have adopted a definite factor given in percentage of one of these ratings for purposes of determining necessary system capacity. If large machines at the end of a heavily loaded line may with improper design result in the loss of other machines due to low voltage, consideration of line spacing and bracing cannot be ignored.

In choosing transformers a definite decision should be reached in the layout of primary and secondary

distribution, and this policy adhered to. I have never seen accumulated data which will prove the best distribution in long primary lines with many transformers, giving good voltage regulation, or large centralized transformer capacity with long low voltage lines. In the case of lighting loads the latter cannot be recommended. However, the economics and safety of high and low voltage line construction must be considered.

In feeder circuit layouts the issue of protection versus service continuity is a predominant one. Continuous operation is, of course, the desire of all mills and power delays are costly. It thus seems that a continual power source is desirable. In steel mills, as in utilities, improved station equipment giving higher capacity and greater reliability, throws the burden of equipment failure in power supply onto the lines themselves. Bolstering of primary feeder capacity would tend to throw the burden back on the station. Such a vicious cycle is costly and is not a direct improvement in low voltage construction, though failures are reduced. With present machines of tested quality available, a desirable low voltage generating equipment having short time overload capacity built into it is installed and if this peak capacity is to be utilized, the basis for load factors should be the continuous rating of the drives. This is apparent because no individual drive is expected to put out its peak rating except for a short time. Since the manufacturers have built into the station unit a short time overload capacity it should be ample to provide for the simultaneous peak loading of the auxiliaries. Using this simultaneous peak loading as a basis for determining continuous generating or line capacity would belie the actual rating of the individual motors. However, as Mr. Nelson has pointed out, this load factor for any drive is a figure difficult to determine and too careful consideration cannot be given it.

In the regulation of low voltage systems the factor of voltage drop is of prime importance, particularly in D.C. systems when the speed of the drive is a function of this voltage. Regulation of lighting circuits cannot be stressed too highly as the main fault of the majority of poor lighting systems is low voltage. Well-planned lighting layouts and first-class lighting units are of little value if the circuit regulation is bad. In the case of synchronous or induction motors the method of starting is a paramount factor, particularly in large machines where across-the-line starting is employed. The factor of regulation enters here as the starting of a power system would be one of high mechanical and electrical strength with each machine individually protected and line breakers set to trip only on dangerous station currents. It would be an interesting development to design and construct a solid low voltage network for power distribution in a steel mill. Granted that this scheme would require maximum copper sizes and sturdy construction and as a result experience. However, its advantage would be the elimination of power delays for any but a major failure.

Alternating Current *Arc* Advance

(*Continued from page 55*)

reacting control. The advantage is a long pertinacious arc and the balancing of the load on polyphase.

High frequency not 200 or 500 cycles but in the order of 100,000 cycles obtained by spark gap or tube oscillations is a decided improvement for both A.C. and D.C. welding machines which extends arc welding further into the light work field and helps considerable on some of the non-ferrous alloys such as aluminum, monel and stainless. With the "Jump Spark" type of high frequency the electrode need not be touched to the work as the H.F. jumps the gap and the welding current follows the thus broken down electronic path. It is this feature that allows thin work to be done by low accurately controlled current and voltage so that the thin work is welded but burned through. Currents of ½ to 50 amperes are usable by this process. Similarly, low melting point metals are weldable where the ordinary arc would voltalize them. This H.F. is useful in double carbon and hydrogen flame welding also. There is also a modified form of high frequency, good for alternating current machines, only, which consists of controlled oscillation capacity and one form of this where the control is a multi-tapped voltage control of the condensor gives very smooth results. There is no jump spark effect here and contact must be made to start the H.F. effect.

This form of high frequency is good for light work and non-ferrous but not as thin or low melting work can be done as with the jump H.F. This extends the arc from, say, 65 amperes town to 25. While it will not jump the gap, that is the arc will not start without touching the electrode, there is no tickling sensation which so far has been an objection of the high frequency.

TRAINING EN

By J. EDWARD JOHNSON

Director of Education & Training

CARNEGIE-ILLINOIS STEEL CORP.

PITTSBURGH, PENNA.

Presented before the
Pennsylvania Society of Professional Engineers

▲ TRAINING an engineer is an undertaking which requires the careful and patient attention and effort of a number of individuals or groups. In the first place, the individual concerned must be determined in his desire to become an engineer and be willing to pay the price involved. His decision in this matter should not be arrived at by any hit or miss plan, nor should he go blindly into the study of a particular profession because of some acquaintance whom he knows to be successful. Most high schools and preparatory schools have guidance bureaus where information can be obtained. Advice may be sought and counsel is gladly given. Men already in the profession gladly advise and assist the student and, in many cases, young men are employed in some minor capacity of some professions before actually embarking on the long, hard grind of preparation. Assuming the individual has had the advice and counsel of men already in the profession, that he has some knowledge of what is required in a particular profession and that he has the necessary characteristics and qualifications, he is now ready to embark on his formal schooling in some college or university.

COLLEGES AND EDUCATIONAL INSTITUTIONS RESPONSIBLE GROUPS

The college or educational institution is the second point upon which responsibility rests. Through 4, 5, or 6 years or more, every effort is made to present such subjects and direct the study so as to make possible the achievement of the individual's desires. In spite of the individual's good intentions and the colleges excellent tutoring, training is not complete.

It is idle to assume that academic instruction, however excellent it may be, completes the individual's training; that having been exposed to a great amount of theory, he will be able to discharge the required duties in his chosen profession.

Graduation is marked by commencement exercises. Commencement is certainly a logical word as the individual, whether in engineering or any other pursuit, is just commencing and his training will go on and on. If for no other reason than the constant change taking place all around us in all pursuits, the individual's training must continue. New ideas, new methods, new problems in all fields, demand constant development of an individual, whether he be 18 or 80 years of age. In this highly competitive age of ours, he who rests on his laurels will be passed.

The third group upon which responsibility rests is the industry or profession. For the new man, after graduation from college, his first job requires careful breaking in. This is a matter of job instruction which continues as long as he remains on the job.

It is reasonable to suppose that once an individual has chosen a particular profession, he honestly expects to be successful in it. The colleges make every effort to see to it that the individual is given the proper training, and industry, now more so than ever, makes every effort to start the new man correctly. The colleges also follow-up their graduates and through personal visits or by sending out questionnaires an attempt is made to determine ways and means of improving curricula.

Recently, Professor Frank L. Eidmann of Columbia University undertook to ascertain how well industrial executives were satisfied with young engineering graduates whom they employed. It was found that a large number of employers reported only a low percentage measured up to expectations. This led him to search deeper.

Here are some of the points developed which were presented in a paper by Professor Frank L. Eidmann at the annual meeting of the Middle Atlantic Section of the Society for the Promotion of Engineering Education, held at Philadelphia, Pennsylvania, December 11, 1937. The following few paragraphs are quoted from this paper:

"The estimates from the various companies as to the percentage of young engineers who prove satisfactory range all the way from 10 to 100 percent, with the largest number distributed fairly evenly between 50 and 90 percent.

"An official of a large company told me that his company expects engineering graduates, after a period of orientation, to stand 'head and shoulders' above the men who come up through shop positions, and to

NG ENGINEERS *for* INDUSTRY

J. E. JOHNSON

be similarly superior to graduates of liberal arts and sciences. He stated that engineering graduates in very few cases measure up to this expectations. The president of a company wrote:. 'It depends on what you mean by "satisfactory". Some are content to stay where they are left, and others want to climb to the top. Of course, it is the latter type, when restrained by reason, that we prefer'. Similarly, the vice president of another company wrote: 'Answer to this question depends upon the definition of the word "satisfactory". Probably 90 percent of these young graduates turn out to be reliable, hard-working employees, but not more than 25 percent, and probably less, turn out to be top-notch engineers or salesmen'. Another large company reports: 'Our records show that approximately 70 percent of the college men who come with the company remain with it. Naturally, some of these are a great deal more satisfactory than others. There are, undoubtedly, a number of them who merely hold routine jobs and will continue to do so as long as their work holds up to a reasonably exacting standard.' An engineering executive of another large company states: 'Over 90 percent of the college graduates whom we take in do work which is satisfactory, but this does not mean that they are outstanding. Probably not 10 percent would qualify as outstanding with respect to knowledge and their ability to apply it'. Similarly, another very large firm reports: 'Probably 90 percent of them are *usable* in the organization, but only a relatively small percentage turn out to be really satisfactory'.

GOOD PERSONAL TRAITS AND ATTITUDE ARE HELPFUL

"As to those young engineers who prove unsatisfactory, the comments from industry indicate almost unanimously that personal traits and attitude are responsible. The fault most mentioned in the letters is 'the inability to get along with his associates', and, to introduce the element of time, 'lack of ability to fit in quickly with their fellow employees and to make friends readily'. Next stands 'over eagerness for advancement'. Other faults mentioned are: 'Unwillingness to prepare for advancement over long enough period;' 'lack of aptitude for engineering work;' 'inability to adapt themselves to the routine of operating work and at the same time avoid getting into a rut;' 'lack of initiative;' 'inability to grasp practical aspects of problems and situations;' 'impractical and unable to apply themselves;' 'general inability to sell themselves;' 'lack of willingness to work.' "

Similarly, at the Twelfth Annual Industrial Conference at Rutgers University, September 9, 1937, a Report of a Survey of Adjustment of College Graduates in Industry was presented. This survey differed from the one just mentioned in that the questionnaires were distributed to college men in the industries.

Such questions as: "What subjects not pursued in college would have helped you most at present?"; "Is your present position in the field of your college training?"; "Do you consider your college education a good investment?"; "If you were called upon to address a group of seniors on the problems of adjustment in industry, what is the most important point you would discuss?", and many others, is certainly an indication that the colleges are making a sincere effort to produce the type of men required.

In the proceedings of this conference, Professor Fred H. Pumphrey states:

"It seems to me that the opportunities for the solution of this problem lie in four general directions. The first involves better educational situations in our schools. The second will be in the field of continued social education of the college graduate. A third possibility is a well planned transition program in industry. Last, but not least, is the development in industry of an idealism which will eliminate many undesirable practices, which, at present, require an adjustment on the part of the college man."

FIRST YEARS FOLLOWING GRADUATION ARE MOST IMPORTANT

Assuming now that all the preliminary work has been completed and that the individual has been graduated

from college, the young man obtains his first position as an engineer. The first few years following graduation are probably the most important, as well as the most difficult, in his career. This is the period of adjustment to commercial life, and his entire future will be influenced by the type of work he performs and the work habits he acquires during this critical stage.

It would be folly for me to attempt to give you a "cut and dry" method to follow during these critical years. Each industry must determine this for itself. What might prove highly successful in one type of industry may fail in another. There are, however, some basic points which should be considered.

Since there are many types of engineers and, in many cases, many specialized branches of each type, the first step is certainly to determine the particular type or branch which he is best qualified to follow. Secondly, plan the work for developing the individual in successive steps beginning with the simple and progressing to the more complex.

OUTLINE OF ESSENTIAL OBJECTIVES TO BE DEVELOPED

Certain objectives are essential and should be developed, a few of which may be:

1. Develop qualified engineers to carry on the important and ever increasing development work in connection with the profession or industry. Qualified men are difficult to obtain. Even when obtainable, outside help in most cases must be oriented; the men must learn the particular business.
2. Develop those personal traits and characteristics which are known to be most desirable. Careful attention by the supervisory force will eliminate a difficulty often prevalent in the college man—inability to get along with associates.
3. Temper inordinate eagerness for advancement. The college man often fails to comprehend the great amount of practical experience necessary for a well rounded training.
4. Develop willingness to prepare for advancement. This requires, in most cases, a long period of careful attention to detail from the practical standpoint.
5. Develop aptitude for engineering work. Eliminate resistance to routine engineering practice which is so essential for a thorough knowledge of engineering problems.
6. Develop initiative and self-confidence. Schedule the day-to-day experience or work, route through all phases of the work and place him on his own. He must be taught to accept responsibility.

These objectives, if attained, will eliminate the faults most frequently mentioned in letters received by Professor Ridmann and included in his paper. While these objectives may not be all inclusive, nevertheless, they are basic and can be used as a start.

PROCEDURE FOR TRAINING SHOULD BE CAREFULLY PLANNED

Once objectives have been established, the procedure for training should be carefully planned. Definite, pre-determined plans flexible enough, of course, to allow for contingencies, should be prepared. Training should follow the actual performance of duties and progress, in easy stages, from the simple to the more complex. Interest must be maintained and there is no better way to do this than by doing a job which has some value. Exercises, which will be scrapped when completed, while of benefit in developing skill are not considered as good methods in training at this stage. The graduate has spent years in college on one exercise after the other. He now craves real productive work. Give him a job, a real job, with some responsibility; make him understand that the drawing or machine part will be used, or that his particular operation is a part of the overall particular operation, and he feels he is of value.

Before commencing to work, make him feel he is a part of the organization, introduce him to his fellow workers. Explain any general rules governing the office, department, or plant, and, by all means, policy. If there are safety hazards, stress safety.

In developing the plan for day-to-day experience, set up a control chart or some device to avoid omission of types of work and let the individual know what is planned. In this way, he, too, can check, as time goes on, his advancement in the detailed plan.

Trade and engineering magazines should be circularized to permit not only this group of engineers who are in training, but all engineers to keep abreast of the times.

Conferences and class sessions often have a definite place in such training programs. When held, it is preferable to hold them during working hours.

EXAMPLES OF TRAINING IN CARNEGIE-ILLINOIS STEEL CORPORATION

It may be of interest to the group to cite a few concrete examples of training now in progress with the Carnegie-Illinois Steel Corporation.

Most of the engineers inducted into our organization are placed in a metallurgical group known as the Observation Corps. It matters not whether they be mechanical, electrical, industrial, civil, or metallurgical engineers. We have found by experience that a man will be more valuable in any capacity in the steel industry for having had experience with the progressive stages in the making, shaping, and treating of steel. His period of employment in an Observation Corps may be from six months to two years, depending upon his ability and the openings available for advancement. While in the Observation Corps, he is routed through every producing department in a plant and performs an actual job in connection with producing steel. Briefly, his duties are:

In the open hearth, watch the charging, working, tapping and pouring of the heat of steel, record all pertinent data, run carbometer tests for carbon content, help the melter calculate the necessary additions and generally make himself useful to the melter foreman. At the soaking pits, take the temperatures of the ingots in the pits, keep the heater informed of temperatures

observed and record all data relative to the heating of the steel. On the rolling mill, he is charged with reporting the rolling and finishing characteristics of the steel, recording any defects which might possibly develop. In the chipping yard, the observer records the types of defects found on each bloom. In the office, statistical work of correlating the open hearth and rolling mill irregularities *against* the types of defects found in the yard is carried out by the observer. In the laboratory, routine physical tests are made by the observer, troubles are investigated and heat treatments are studied. We believe that this is as rounded an experience as we can give these men to supplement their schooling and start them in the business of making steel.

Periodically, these men are rated by their immediate superiors. In addition, an effort is made to ascertain what type of work they would like to follow. While in the Observation Corps, we observe their progress and ability, and in turn they observe the entire organization and try to select the type of work they feel best fitted to do or in which they are most interested. As vacancies occur the best equipped men are given first consideration.

In addition to this work, which is, in many cases, hot and dirty and follows different shifts, various conferences are held to discuss the problems which arise in the fulfillment of their regular duties.

Definite class work, on company time, using the Corporation text on The Making, Shaping and Treating of Steel is contemplated. This will permit a closer correlation between theory and practice.

This plan of training men in the Observation Corps has been quite successful and many individuals have benefited by being transferred into better positions of a permanent nature.

A second group of engineers in training are Industrial Engineers. Definite schedules have been prepared with allotted periods of time, for approximately two years, covering work of a nature performed in this department. Some of the main types are: Method Studies, Cost Analysis and Investigations, Job Evaluation, Time and Motion Study, Wage Incentives, Organization, Theories, Charts and Plans, Controls—Standard Budgeted Cost and Routing and Specific Projects.

In addition to this day-to-day experience, for a period of approximately six months the group is assembled bi-monthly for a two-hour discussion of the various operating units. Interest has been unusually high and men and Management are well pleased with the results.

A third plan is devised for those who would perform the duties of mechanical, electrical and civil engineers. Two classes of personnel are involved in this plan; namely, high school graduates and college graduates. For the high school graduate, his training will be a combination of appropriate experience through the day and study in the evenings at one of the colleges in the district. The college graduate training will be accomplished by following a definite plan of day-to-day experience. All phases of work in each branch of engineering will be covered, and, if a particular plant does not make possible experience in any phase, arrangements will be made for temporary transfers to another plant at which the experience may be obtained.

Day-to-day experience, or the experience on the job, will be a combination of duties involving office as well as field work.

Summarizing the training procedures discussed in the preceding part of this paper, we can say that the college graduate is afforded an opportunity, through lectures and conferences, actual work and observation, to gain a general knowledge of the work and scope of the plant and to fit, eventually into the right place. During the training period, varying in the number of years, the individual is routed within and between departments. In this way, he acquires a comprehensive idea of the whole plant and its inter-relationships. During this period he is definitely determining, with the aid of his supervisors and the training staff, the phase of the business in which he will best serve himself and the enterprise.

Modern machinery and equipment are essential, but trained workers to supplement these improvements are equally important. Through a training program, any industry can hope to lead the way toward a better product by virtue of the provision of better personnel.

REPUBLIC OPENS W

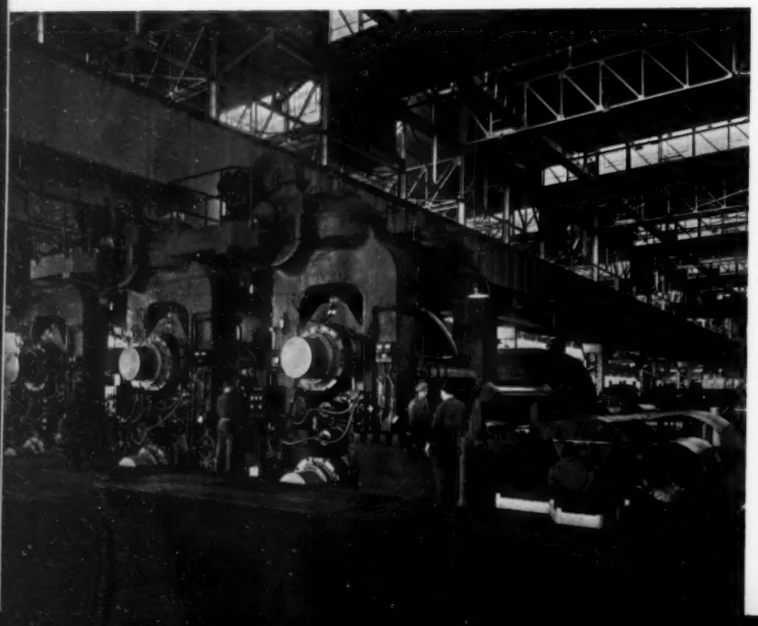
Strip M

Tom M. Girdler, chairman of the board, Republic Steel Corp., addressing the large group of newspaper and trade paper editors, who were guests of the Corporation at a dinner following the formal opening of the new Republic strip mill at Cleveland. R. J. Wysor, president (extreme left) and C. M. White, vice president in charge of operations (extreme right) also spoke. To the right of Mr. Girdler is A. C. Ernst, president, Cleveland Chamber of Commerce, who introduced the speakers.

▲ REPUBLIC Steel Corp. formally opened its new 98″ hot and cold strip mills in the Cuyahoga Valley at Cleveland, Tuesday, March 15th, with a large group of newspaper and trade paper editors present for the event. The mill is the largest, fastest and most modern continuous strip mill in the world.

Ushered through nine large buildings comprising the plant by Republic executives, the editors witnessed the operation of the mills which roll strip steel 94 inches wide from slabs which speed through a series of electrically controlled roughing and finishing mills to the coiler almost a quarter of a mile away in as little as 240 seconds. Steel moves through this mill at speeds up to 2121 feet per minute and is wound into coils weighing as much as 12,500 pounds apiece. The plant has a capacity for production of a million tons of hot and cold rolled sheet and strip per year.

The 98 inch 3-stand tandem continuous cold reduction can roll strip down to as thin as 24 gauge. Thickness of strip is measured as it comes out of the cold mill at high speed by a sensitive micrometer which registers on a large dial variations in thickness of even one thousandth of an inch.



The mill buildings cover 21 acres and stand on a 182-acre site, part of which is land which was made by changing the Cuyahoga River channel, a feat which required removal of more than a million cubic yards of dirt. The most modern types of handling equipment; electrical devices which give absolute control of working temperatures and speeds throughout the hot rolling, pickling, annealing and cold rolling departments; and scientific lighting provide efficiency and ideal working conditions throughout the plant, which has a potential employment capacity of over 2000 men. A large welfare building and an office building complete the group.

Embodying in its design every technological improvement that the country's best mechanical, electrical and metallurgical engineers have thus far developed in the art of processing steel, the new mill is man's latest and mightiest achievement in the production of one of his most important manufactured products, strip steel, the basic product from which are fabricated automobile bodies, refrigerators, washing machines, and a thousand and one other items that make possible our modern industrial civilization.

The new mill can roll long, giant sheets up to 94 inches, that is almost eight feet, wide—the widest sheet ever to be rolled on a continuous mill on a production basis. Ribbons of steel, some of them a quarter of a mile long, are rolled out of the hot mill at the rate of over 35 feet in one second (2121 feet per minute), and out of the cold mill at the rate of almost 14 feet in one second (800 feet per minute)—both new world records.

The mill has a nominal rated capacity of 70,000 gross tons per month. Although every proven mechanical device has been built into the equipment, the new mill will give employment, when operated at full capacity, to 2000 men.

GENERAL DESCRIPTION

The mill is located on a 182-acre site six miles from the mouth of the Cuyahoga River. For a distance of almost half a mile at this point the river itself was moved to make way for the mill, more than 1,000,000 cubic yards of dirt being moved in excavating for the

ENS

WORLD'S LARGEST

Strip Mill

new river channel and in filling the old river bed and a nearby swamp. More than 19,000 concrete piles averaging 40 feet in length were driven into the new fill and 120,000 cubic yards of concrete were poured to provide a foundation for the superstructure and the heavy mill equipment.

The appearance of the mills is that of two enormous industrial plants. Actually, however, these two structures consist of a total of nine large buildings. In addition, there is an office building with completely equipped testing and metallurgical laboratories in the basement, a welfare building with shower and dressing room accommodations, and a machine shop, a carpenter shop and a large pump house on the river bank. Altogether, 21 acres are under cover.

The Cleveland strip mill is the largest mill ever designed by an architect. The architect for this construction was Albert Kahn, Inc., Detroit.

Inside the mill are thousands of tons of massive machinery and equipment, controlled for the most part by electric push-buttons, and operated with the precision of a craftsman-made watch. The location of every machine and of every item of equipment was scientifically worked out to make the operation and management of the mill, even though the massive machinery had to be spread out into 21 acres of buildings, as efficient as any large-scale plant ever built.

Particular attention was paid to the fast-growing trend throughout the steel industry of making "tailor-made" products, products made to order to meet the particular requirements and specifications of each customer. Despite the fact that the mill is geared to high-speed production of nearly a million tons per year, the mill is designed to smoothly and efficiently turn out relatively small orders of specially processed steel, and there is always a continuous flow of production from unit to unit and from department to department, without any back tracking or lost motion.

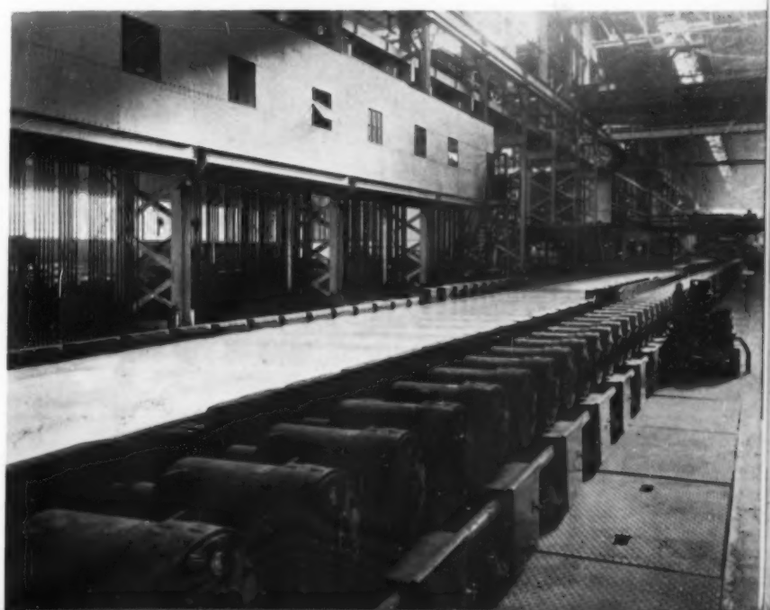
This train of six hot mill finishing stands can roll strip at a delivery speed of 2100 feet per minute, making it the fastest wide continuous strip mill in the world.

Mill equipment is integrated into the following seven important processing units:

1. Furnaces, where slabs of steel are heated to a white-hot temperature.
2. The hot mill, where the white-hot slabs are rolled out into light steel plate or long thin strips.
3. Hot mill finishing, where the hot rolled plate or strip is processed and cut to desired length.
4. Continuous pickling, where scale is removed from the surface of strip which is to be further processed.
5. The cold mill, where higher grades of strip are rolled out to lighter gauges.
6. Annealing furnaces, where higher grades of strip steel are heat treated, and
7. Cold mill finishing, where cold finished strip is cut to desired lengths and given final surface treatment.

The September issue of the Iron and Steel Engineer will contain the complete technical description of this latest strip mill.

Strip 94 inch wide coming down the hot mill runout table. The 278 motors which drive the runout table rollers are D.C. units. This mill is the first ever designed with D.C. instead of A.C. runout table motors.



NEW PLANT MAKES ELECTRIC STEEL

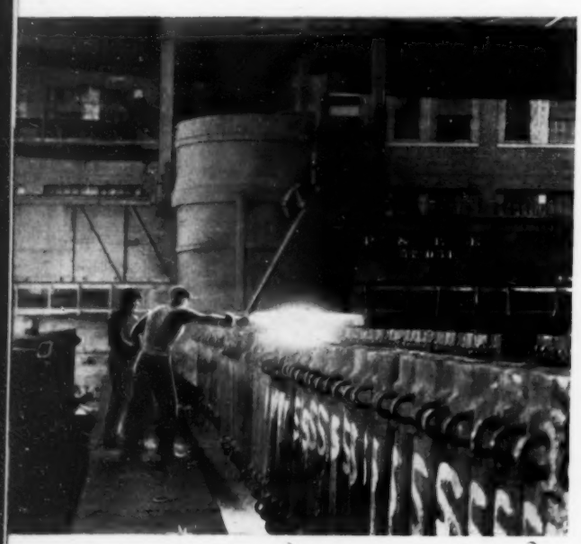
▲ Half a century ago there was established at Sterling, Illinois, a small plant devoted to wire drawing and the manufacture of wire products. By a recent program of expansion, the Northwestern Barb Wire Company has extended its activities to include the production of its requirement of steel.

This plant is of unusual interest because it marks a departure from beaten paths of steel production. It represents an answer, in a particular case, to the question: "Can carbon steel be produced economically in small tonnages?"

For many years the Northwestern Barb Wire Company has purchased wire rods. Its tonnage grew gradually until finally the question was raised as to the feasibility of producing its own steel. The tonnage requirement, on the order of one hundred thousand tons a year, was too small to justify production by usual methods. The somewhat unusual was therefore considered and the procedure described in following paragraphs was eventually determined upon. This does not represent a new process. It comprises, rather, an unusual combination of production methods, each of which has been previously sucessfully developed.

The new plant at Sterling comprises essentially a steel-making department for the conversion of scrap in electric furnaces and the production of small ingots, a roughing mill to reduce these ingots to billets, and a rod mill for the further rolling of the billets into wire rod. The plant is located contiguous to the Rock River and adjacent to the wire mill.

Pouring ingots prior to pushing them through a 65′ hearth furnace.



SCRAP HANDLING

Scrap, in prepared form, may be received in a yard at one end of the steel-making department. This yard is served by a fast, magnet-handling gantry. Two other large yards nearby, served by gantry cranes, may be used either for scrap preparation or for supplementary storage. Scrap may be received at either of these yards by truck or by rail. In all, a storage capacity of 20,000 to 30,000 tons is available.

The scrap, after being sorted to eliminate cast iron, copper, zinc and other alloys, is sheared to charging box size and loaded into transfer cars, where it is delivered to the furnace charging department. Here it is loaded into cylindrical charging buckets about 6 ft. in diameter by 8 ft. high, with orange-peel bottom. Each of these buckets holds about 5 tons of scrap. The scrap is charged from the buckets into the furnaces by

One of the electric furnaces capable of handling heats of 15 gross tons.

Written by Gordon Fox, Vice President, Freyn Engineering Company and reprinted from "Freyn Design" by courtesy of Freyn Engineering Company.

means of a 20-ton overhead traveling crane.

ELECTRIC FURNACES

Two electric furnaces are installed handling heats of about 15 gross tons. These furnaces are of Lectromelt type and are provided with roofs which may be rotated to provide clear access for charging. The two furnaces are arranged on 40 ft. centers, with their pouring pits facing away from each other. The furnaces are set at floor level and the space between them is available for supplementary charging of fluxes, additions, etc. Due to the light-weight scrap used, 3 to 4 charging buckets of scrap are required to make up one 15-ton heat. Each charge is melted down before the next bucket is dumped. About an hour is required to melt down the heat. This is followed by a brief period of refining, in which a single basic slag is used. Tapping, bottom patching and charging operations require about 20 minutes. The time of a heat is about one and one half hours. Each furnace averages about 12 heats daily.

INGOT POURING AND HEATING

Each heat is poured into a ladle and carried by a crane to the pouring aisle where it is tapped into ingot molds approximately 8 by 8 by 70 inches. Each ingot weighs about 1,000 lbs. Individual big-end-up molds are used, the bottom of the mold being closed with a tapered pin projecting about 2 in. below the mold. The ingot has a slight taper. The molds are set up in parallel rows on cast iron bases, a suitable pouring platform being located between the rows. This method of pouring results in a satisfactory ingot surface and a small pipe well concentrated in the ingot top. Stripping is accomplished by simply lifting the ingot out of the mold with a crane by means of a ½ in. steel loop stuck in the top of the ingot by the pouring crew. The few stickers are usually removed by raising the mold a few feet and dropping it on a heavy cast anvil. The tapered pin strikes first and drives the ingot out of the mold. For those ingots which cannot be removed by this method, a hydraulic stripper is provided.

The ingots are charged into a Freyn continuous heating furnace in two rows, every other ingot in each row being turned to compensate for the taper. No difficulty is experienced in pushing these ingots through a 65 ft. hearth furnace.

At the right is pictured Mr. James Caven Foster, who resigned as general manager of sales, Jones & Laughlin Steel Corporation, Pittsburgh, Pa., effective February 28, 1938 to become president of the Northwestern Barb-Wire Company. Mr. Foster's entire business experience has been with Jones & Laughlin. He went to work in 1913 in the order department, and two years later was transferred to the sales department, where he remained continuously excepting for the period of his service in the American Expeditionary Forces during the World War. He was made manager of Wire Sales in 1932 and general manager of sales in 1935.

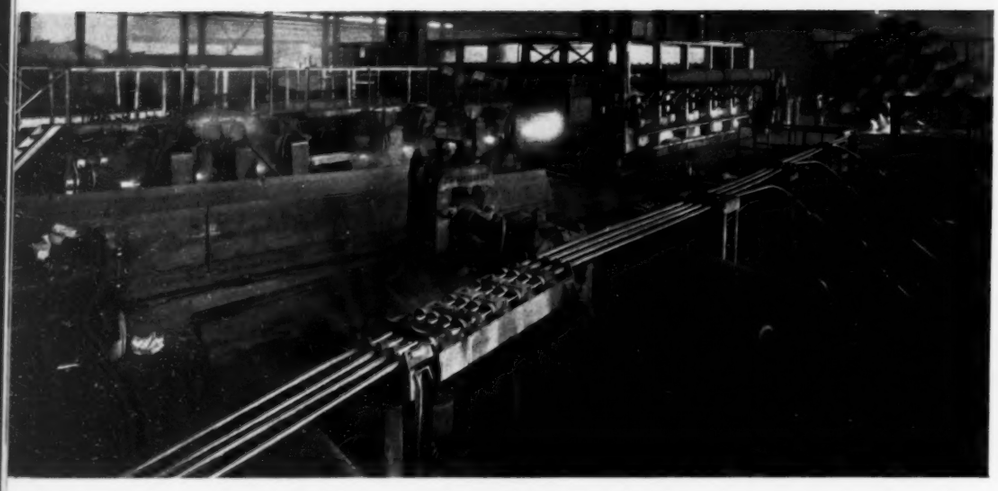
The furnace is equipped with inclined water-cooled skids and is arranged for under and over firing. Heavy fuel oil is atomized by cool primary air at about 2½ lb. pressure, about 10 per cent of the total combustion air being thus supplied. The balance of the air is preheated to about 350 degrees and is introduced through the burners at low pressure. The furnace is equipped with a waste-heat boiler followed by a plate type air preheater. The boiler supplies moderate pressure process steam.

The waste gases, after passing through the boiler are used to preheat the air for the furnace. The stack temperature after leaving the preheater is about 400 deg. F.

Upon delivery from the heating furnace, the ingots are rolled to 2¼ in. billets in an 18 in., 2-stand, 3-high, motor-driven mill. Every other ingot is turned before entering the mill so that they all enter the first pass small end first. The first stand of the mill is equipped with lifting tables while the second stand is equipped with one tilting table. One ingot produces two 2¼ in. billets about 30 ft. in length, sufficient for two 450 lb. coils of rod. After shearing, the billets pass over a transfer to the approach table of the billet reheating furnace. Under prevailing conditions, the billets enter this furnace at a temperature of about 900 to 1,000 degrees. The heating furnace for the rod mill, however, has sufficient hearth area to supply the rod mill from cold billet stock when necessary. The capacity of the roughing mill is about 30 tons per hour, permitting

J. C. FOSTER, President

Ingot heating furnace and 18" mill ajacent to the merchant mill.



Billet heating furnace and rod-mill roughing group.

this mill to synchronize with the operation of the rod mill.

THE ROD MILL

The rod mill includes a continuous roughing group of eleven stands, made up of four 14-in., three 12-in., and four 10-in. stands. This is followed by two looped passes in 10-in. stands, which, in turn, deliver to a finishing group of six 10-in. stands in tandem. The roughing group and the finishing group are driven at constant speed by synchronous motors. The two intermediate stands are provided with adjustable-speed direct-current drives.

The mill is designed to handle two billets in the roughing stands. No. 5 rod is delivered from No. 19 stand at a speed of about 3600 f.p.m. Two and three strands finish simultaneously and pass to four reels. These, in turn, deliver to a cooling conveyor which finally deposits the coils on a star unloading rack. They are handled from this rack by a ram truck.

For finishing guide rounds and rods of heavier section, an additional finishing stand, No. 20 is provided. Room is provided for a duplicate stand No. 21. When finishing through these stands, the finishing group comprising stands 14 to 19, is not operated.

The 18 in. roughing mill is laid out in such manner as to permit ultimate delivery directly from that mill to a merchant mill which may be located in the same building. Merchant bar may then be rolled directly from the ingot. Space is also provided for a future heating furnace of the side door type, which may be used in connection with the future merchant mill for heating small lots of ingots or billets which may have been rolled on the roughing mill and chipped.

ELECTRIC POWER

Power for operating the plant is purchased from the Illinois Northern Utility Company at 13,200 volts. A special form of off-peak contract was developed for this case, under which the load must be restricted during a few winter peak-load hours. The melting furnaces are liberally powered, a 7500 kv. a. transformer being provided for each unit. The large main drive motors are supplied at 2300 volts. Two motor-generator sets provide direct-current at 230 volts. One of these normally supplies the adjustable-speed main-drive motors while the other supplies cranes and auxiliaries. The two sets may be operated in parallel to supplement each other.

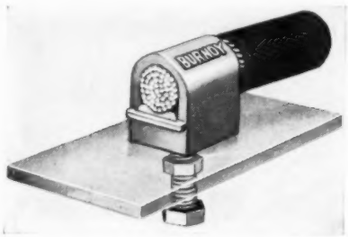
A tie, at 460 volts, is provided between the electrical system in the new mill and the old steam power station which supplies the wire mill. This serves to standby the old station. It also permits the old station to supply some power to the new plant during the hours of peak load.

While, at first thought, it might seem that carbon steel for fencing, nails, etc., could not be made in electric furnaces at a competitive cost, the favorable location of this plant with respect to scrap flow and markets; the low cost of power; the relatively small investment involved; the excellent control of product; all are factors which contribute to the success of this pioneer type of steel plant.

CLAMP CONNECTOR *for* TERMINATING CABLES

▲ Burndy Engineering Co., Inc. (New York) announces a new low-cost clamp connector especially designed for terminating cables to the copper bars extending from each side of current transformers.

The clamp (type KPF) consists of a cast copper body through the bottom section of which a hole is tapped. A ½″ bolt passes through the hole in the copper bar and into the tapped body



Clamp connector especially designed for terminating cables to the copper bar extending from each side of current transformers.

hole where it forces the pressure bar solidly against the cable. By tightening the nut assembled on the bolt, the joint is clamped to the bar and protected against vibration.

Burndy type KPF is readily taped, accommodates a range of cables and can be pivoted upon the bolt to permit cable tap-off at any angle from the bar.

FIVE STAND TANDEM OPERATING AT IRVIN

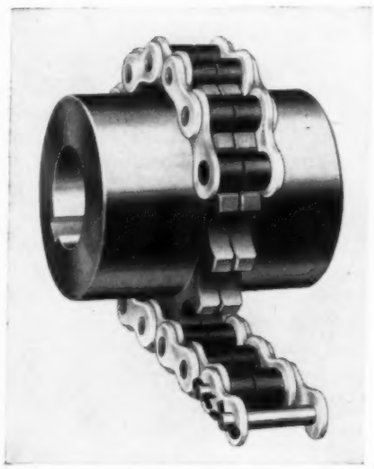
▲ First machinery in operation at Irvin Works, Carnegie-Illinois Steel Corporation's new sheet, strip and tin plate plant near Clairton, Pa., is a five-stand tandem type mill in the cold reduction department.

The mill was given its first rolling test at 8:00 P. M., March 2, just a little more than nine months after excavation was begun at the Camden hill-top site of the plant. The equipment tried has rolls 42 inches wide which are used for cold rolling strip steel to proper gauge for conversion

into tin plate. The five-stand tandem mill, excluding the motors which power it, weighs approximately five million pounds.

Tests of the five-stand cold reduction mill are one of the primary steps before operation of the tin division of Irvin Works. Construction of other tin division units is rapidly nearing completion.

Although much foundation and building construction work remains to be done, all plant equipment is expected to be installed for test operations by July 1.



New type flexible coupling showing divided roller feature.

IMPROVED TYPE OF FLEXIBLE COUPLING

▲ Announcement is made by Link-Belt Company, Chicago, Philadelphia, Indianapolis, of the development of a new flexible coupling, Type "RCB," which embodies major improvements over the company's Type "RC" roller-chain coupling long furnished for connecting shafting in line.

The new "RCB" coupling consists of two cut tooth sprocket wheels (or coupling halves) which are connected by a piece of specially constructed single-width finished steel roller chain, using a recently-patented divided-roller feature which combines the advantage of double roller chain with the more rugged and simple construction of single width chain. The divided roller provides independent roller action for each sprocket, and as the contact between roller and sprocket causes the roller to revolve on its bushing, any tendency to scuff the rollers and sprocket teeth is said to be avoided. Longer coupling life, and extension of the range of efficient application, are claimed for the new coupling.

Other major improvements concern the grease-retaining housing or casing, which, when specified, is furnished for enclosure and automatic lubrication of the coupling. The most outstanding of these improvements is the use of two fittings, 180° apart, inside the housing, to permit packing the housing with grease, without necessity of dismantling. Another improvement consists of furnishing a better seal between the two halves, to avoid leakage of grease. To embody these changes, the size of housing has been increased slightly as compared with that furnished with the "RC" roller-chain coupling.

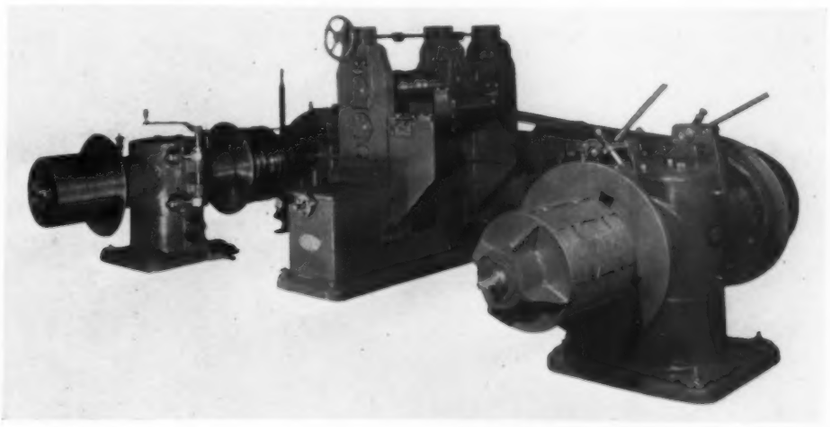
A 1937 edition of illustrated Book No. 1545 gives dimensions, ratings and other data. A copy will be sent to any interested reader upon request addressed to Link-Belt Company, 519 N. Holmes Avenue, Indianapolis, or other office of the company.

. . . NEW DESIGN OF SLITTING-TRIMMING EQUIPMENT

▲ With the speedy continuous production of flat stock, the demand for equally adequate equipment for side trimming, slitting and processing the stock, as well as efficient coiling and uncoiling means, has greatly increased. The Yoder Company has designed and is producing a line of equipment (as illustrated), that greatly cuts the loss of time required by the necessity of replacing coils of stock and removing them when complete. An uncoiling reel stand is provided with two or more drums, which in turn are swung into the line of the processing machines. While the material on the drum in line is being uncoiled, it is securely held in place by a positioning block in the base of the coiler. The drum is swung out of or into position by the operator who releases the position locking device by stepping on a convenient foot lever and by simultaneously pulling on a hand lever, thus releasing the breaking device which permits the free revolving of the drum support on its base. It will be noted that the drum that is swung out of line of the slitting, trimming or other processing machines, is out of the way and free to be loaded during the time that the drum positioned in line is being operated.

All of the drums that make up this multiple uncoiling unit, are equipped with adjustable drag brakes. These brakes allow the drums to pay off at the proper slitting tension, and at the same time, they prevent overruns when the processing train is suddenly stopped. Efficient brakes

Side trimming, slitting and processing equipment that greatly reduces the loss of time required by the necessity of replacing coils of stock and removing them when complete.



are very necessary in pull slitting, and when high speeds are used with heavy coils of material.

The slitting and edge trimming machine as shown, is equipped at the front of the cutters with a combination entering guide, hold down and wiper attachment, which serves to do what the name implies. It guides the material into the slitter and simultaneously cleans the material and places a drag upon the stock as it is being slit. This is especially desirable where pull slitting is employed. The machine is set up for slitting narrow strips, therefore, solid cutters and spacers are shown.

This machine lends itself to many modifications. For instance, when it is set up for side trimming, housing mounted cutters may be used, and by means of a simple screw adjustment, the width of the trimmed stock may be varied as required. The top and bottom cutters being moved without changing their relative adjustment and only several minutes are needed to make this change.

When it is necessary to change frequently from edge trimming to multiple slitting special adjustable cutters can be provided. The adjustments just described, require about one minute of time to complete. When adjustments are made to change the width of the slitted strip, then several minutes are required for changing each set of cutters that are moved.

The tension reel is also of the two drum type similar to the uncoiler above described. Note that the driving mechanism is a unit separate from the coiling drum unit and is connected to the drum which is swung into the slitter line by the simple pull of a hand lever which engages the coupling mechanism. The other drum which has just been swung out of the slitter line in the same manner as above described, is now easily accessible for the helper to wire the coils and to remove them from the collapsed drum.

It is claimed that the use of this Yoder multiple position drum stand not only greatly increases production by shortening the interval of interruption incident to loading or unloading of the drums, but it tends to keep congestion away from the processing line, and contributes to the safety of the handlers of the processed materials. Thus the small additional initial cost of the multiple drums, all of which use the same power unit, practically doubles the capacity of the production line. The use of the multiple drum uncoilers and tension reels are not limited to slitting lineups, but can be used in all other finishing department lines as well, and the same expediting of time and space is apparent. When it is desired to produce coils with different size cores for jobbing trade, tension reel drums of different diameter may be mounted on the same stand and each driven by the same power unit.

This slitting and trimming lineup has been designed by the builders with the thought of durability and the economy of time, continually in mind.

IMPROVED TYPE OF COMBUSTION TUBE

▲ Following a period of research and development of more than two years duration, coupled with cooperative tests in the laboratories of steel and alloy manufacturers, The Carborundum Company now offers the improved "Zircofrax" line of combustion tubes, boats and boat covers. These products are suitable for use at temperatures, well above those required for the analysis of modern high temperature steels and alloys. The raw material used to make these vitrified "Zircofrax" articles is Zirconium Silicate.

Combustion boats and covers will withstand temperatures of 1450° C. and are highly resistant to thermal shock. These properties, coupled with a rugged design and a relatively strong ceramic material, insure a long life of satisfactory service. Gas tight combustion tubes are vitrified above 1600° C. They are resistant to thermal shock well beyond that which may be imposed by combustion furnace operation.

Plain boats and boats with perforated handles in all normally required sizes are available. Plain combustion tubes and also tubes with one end tapered are made in standard sizes from $\frac{3}{8}$″ to $1\frac{7}{8}$″ inside diameter. Special sizes of boats and tubes can be made on order.

NEW LITERATURE

▲ The Independent Air Filter Company, Inc., Chicago, Illinois, has issued an attractive bulletin on "Kompak" air filters. The bulletin, No. K-120 includes information on variable velocity from 25 FPM to 36 FPM—15 to 1 ratio of filtering medium to face area, made possible by the continuous hinge holder design, low refill cost, high cleaning efficiency, replacement simplicity and several other unique features. Anyone desiring one of these should address: Independent Air Filter Company, Inc., 228 North La Salle Street, Chicago, Illinois.

▲ A new four-page folder, attractively printed in blue and black, and featuring the new U.S.S. Storm Seal Galvanized Roofing, has just been issued by the United States Steel Corporation Subsidiaries, 434 Fifth Avenue, Pittsburgh.

Enlivened by cartoon illustrations, the new folder tells the five reasons why U.S.S. Storm Seal is a leakproof roofing. Economies of this attractive, modern galvanized roofing design are also explained, with full instructions provided for applying Storm Seal.

Other new roofings, U.S.S. Syphon Seal $1\frac{1}{4}$″ Corrugated and U.S.S. Syphon Seal 2 and 3 V-Crimp Roofing, are depicted on the back page of the folder, where are shown the most popular roofing accessories for Storm Seal and Syphon Seal.

▲ Quigley Co., Inc., 56 W. 45th St., New York, has just issued an 8-page bulletin describing the important advantages obtained by use of Insulbrix in hundreds of installations.

Insulbrix are light weight low heat storage insulating fire brick, which combine the advantages of a high refractory and an efficient insulator of low heat storage capacity.

Insulbrix are used for direct exposure to flame and gases, in boiler furnaces, ovens, kilns and other high temperature equipment.

They supersede use of thick walls of heavy refractories which are sluggish to heat, slow to respond to load variations and scatter costly B.t.u. to the air.

The important advantages of Insulbrix use are fuel, time and labor saving, increased production, higher efficiencies and lower operating costs.

ADVERTISING PAGES REMOVED

ITEMS OF INTEREST

Lewis M. Parsons, was recently elected vice president in charge of sales and a director of the Jones & Laughlin Steel Corporation, Pittsburgh.

After leaving University of Pennsylvania in 1917 where he was on the varsity crew and the Freshman football and swimming teams, class of 1919, to join the Navy during the World War in the destroyer service and later in the Naval Flying Corps, young Parsons entered the employ of the Bethlehem Steel Company in the sales division. He was made assistant manager of sales, Philadelphia office, in 1932, and manager of sales at the same office in 1936.

▲

Howard F. Martin, an active member of the Association of Iron and Steel Engineers for over twenty years, has been named the superintendent of maintenance of the Jones and Laughlin Steel Corporation's plant at Aliquippa, Pennsylvania. Mr. Martin, who has been with the Jones and Laughlin organization since 1923, has had a wide experience and knowledge in supervising and organizing, together with construction and operation of both electrical and mechanical mill equipment, as well as all other maintenance branches in various mills and industries. G. Rees Carroll, formerly electrical superintendent of the same plant, has been appointed assistant superintendent of maintenance. Mr. Carroll has been located at the Aliquippa Works since 1923. He is a past president of the Association of Iron and Steel Engineers.

▲

L. D. Smith has been elected a vice president of McKeesport Tin Plate Company, McKeesport, Pennsylvania, in charge of operations in the tin plate division. Thomas D. Douglas has been elected secretary.

Frank J. Carr has been appointed assistant to the president of the American Steel and Wire Company, subsidiary of the United States Steel Corporation. Mr. Carr for the past four years has been comptroller of the Tennessee Valley Authority at Knoxville, Tennessee, and previous to that was comptroller of Aviation Corporation and subsidiaries after having held a similar position with Hahn Department Stores.

A native of Batavia, Illinois, where he was born in 1892, Mr. Carr attended public schools there and in nearby Aurora, Illinois, before going to the Wharton School of Finance at the University of Pennsylvania. He was graduated in 1915 with a degree of bachelor of science in Economics. During the World War he was a lieutenant in the ordnance department of the U. S. Army.

▲

Joseph Luchansky, formerly assorting room foreman at the tin mills of Carnegie-Illinois Steel Corporation, Farrell, Pennsylvania, was made assistant chief inspector, tin division, of the Carnegie-Illinois Steel Corporation, Irvin, Pennsylvania.

▲

Alfred J. Diefenderfer was made superintendent of the new slabbing mill at Edgar Thomson Works, Carnegie-Illinois Steel Corporation, Braddock, Pennsylvania. Mr. Diefenderfer, a chemical engineering graduate of Pennsylvania State College, has worked in various plant operating capacities at the Farrell and Sharon plants of the company since 1912, and has been assistant rolling superintendent at Farrell since 1929.

▲

Marlin C. Schwab succeeded Alfred J. Diefenderfer as the assistant rolling superintendent for Carnegie-Illinois Steel Corporation's Farrell Works, Farrell, Pennsylvania. Mr. Schwab, following his graduation from Gettysburg College with a bachelor

LEWIS M. PARSONS

HOWARD F. MARTIN

G. REES CARROLL

of science degree, was employed in the laboratory of Farrell Works in 1927. He later transferred to the blast furnace department and since 1930 has been assistant metallurgist.

▲

Kemp G. Fuller has been appointed manager, market research and sales statistics, United States Steel Corporation of Delaware, with offices at 436 Seventh Avenue, Pittsburgh, Pennsylvania. Mr. Fuller was formerly manager, market research and sales statistics, Carnegie-Illinois Steel Corporation.

After graduation from Dartmouth College in 1921, Mr. Fuller took a post-graduate course in business administration, and has been engaged in market research and sales work since 1922.

▲

W. F. McGarrity has been appointed chief metallurgist for the Carnegie-Illinois Steel Corporarion's new Irvin Works, near Dravosburg, Pennsylvania. Mr. McGarrity formerly was a sheet metallurgist at the company's general offices in Pittsburgh, and previously was an observation corps foreman in the Youngstown, Ohio District Works.

▲

Paul H. Hake has been named superintendent of blooming and rolling mills at the Brier Hill plant of Youngstown Sheet & Tube Company, Youngstown, Ohio, going there from the Gary, Indiana, works of Carnegie-Illinois Steel Corporation, where he had been turn foreman in the billet mill since 1924. He first entered the steel industry at the Brier Hill Steel Company, Youngstown, where he remained until 1922, when he became associated with Inland Steel Company, at Indiana Harbor, Indiana.

▲

Clayton S. Coggeshall has been made general assistant to R. B. Beale, manager of the turbine division, central station department of the General Electric Company. He was formerly manager of sales of the turbine division, Lynn River Works. Mr. Coggeshall, born in Emeryville, California, was graduated from Cornell University in 1911, and immediately enrolled in the G. E. student engineering course at Schenectady, New York. After four years in the test department, he joined the turbine sales department. In July 1918, Mr. Coggeshall was sent to Lynn to take charge of the turbine sales office, and in 1933 was made sales manager of the Lynn section, turbine division, a position which he has held up to his present transfer to Schenectady.

▲

John L. Kerr, former turbine specialist in the central district of the General Electric Company, succeeded Mr. Coggeshall as manager of sales of the turbine division, Lynn River Works. Mr. Kerr, a native of Tennessee, was graduated from the University of Tennessee in 1912, and took a special graduate course at M. I. T. the following year. He was on test in Schenectady and Pittsfield from 1913 to 1917, after which he joined the turbine sales department at Schenectady. A year later he was transferred to the Lynn section, and in 1928 was made turbine specialist in the Chicago office.

John Hulst, vice-president of United States Steel Corporation (seated in front center) recently celebrated his 66th birthday. With him were Col. A. H. Swartz of Cleveland (front row at left) and Walter Rachals, assistant to vice-president of United States Steel Corporation (front row at right); standing at rear (left to right) are C. F. W. Rys, chief metallurgist of Carnegie-Illinois Steel Corporation, Pittsburgh; John Sias, assistant vice-president of United States Steel Corporation, New York, and H. J. Davis, formerly superintendent of the Clairton steel and coke works of Carnegie-Illinois Steel Corporation.

John Hulst, vice-president of the United States Steel Corp., celebrated his 66th birthday February 20 in the Hotel Pennsylvania, where he has made his home since the hotel was opened in 1919. With Mr. Hulst as his guests were some of his oldest friends; men who have known him all their lives and whose careers have marched with his over the past 40 years. Among these were Col. A. H. Swartz, who has known Mr. Hulst all his life and who was formerly associated with him in the steel business; C. F. W. Rys, chief metallurgist of the Carnegie-Illinois Steel Corp.; John Sias, assistant vice-president of the U. S. Steel Corp.; H. J. Davis, retired but formerly general superintendent of the Clairton Steel and Coke Works, and Walter Rachals, assistant to the vice-president of the U. S. Steel Corp. Part of the entertainment provided by Mr. Hulst's steel associates was the showing of a motion picture of the launching of the *John Hulst*, an ore boat more than 600 ft. long.

▲

Frank Theiss has resigned as superintendent, sheet galvanizing department, Continental Steel Corporation, Kokomo, Indiana, to become associated with the Bethlehem Steel Company, Buffalo, N. Y.

▲

It was erroneously reported in these columns that Carle Vande Bogart, formerly of the New Haven Sales office of the Rockbestos Products Corporation, would be located in Chicago. Mr. Bogart will have charge of the Detroit branch of the Chicago office of

(*Please turn to page 85*)

ADVERTISING PAGES REMOVED

S. R. THOMAS

GUSTAV A. MERKT

PAUL H. DIVER

the Rockbestos company. His headquarters will be Room 612, Stephenson Building, Detroit, Michigan.

▲

S. R. Thomas has been appointed chief engineer of Bantam Bearings Corporation, South Bend, Indiana. For the past year and a half, Mr. Thomas has been manager of the automotive bearing division coming to Bantam after an association of four years with the Cord interests where he was chief engineer of Auburn, Cord and Duesenberg. This advancement was made to utilize more broadly Mr. Thomas' twenty-four years experience in a wide variety of engineering projects and to consolidate under one head the widening scope of engineering development at Bantam. He will continue in charge of the automotive work.

▲

Robert S. Neblett has become manager of sales, Schenectady section, turbine division of the General Electric Company. Mr. Neblett was born in Texas and attended Georgia Tech. Upon graduation in 1923, he entered G. E. Test. After two years in this course, he became an engineer in the contract service department, and a year later was made requisition and proposition engineer in the turbine sales department at Schenectady, New York.

▲

Obituaries

Paul H. Diver, 65, sales manager in charge of the magnet department of the Ohio Electric Manufacturing Company, died Saturday, February 27, 1938, of coronary thrombosis at St. Lukes Hospital, Cleveland, Ohio. Mr. Diver was born near Philadelphia, where he made his home until coming to Cleveland in 1908. He was for ten years a freight agent for Mutual Transit Company, now a part of the Great Lakes Transit Corporation. He first became associated with the Ohio Electric Manufacturing Company in 1918. Mr. Diver was an associate member of the Association for over twenty years. His many friends were deeply grieved to hear of his passing.

▲

Gustav A. Merkt, manager of the combustion control department of the Morgan Construction Company, Worcester, Massachusetts, died Feb. 20. For many years he had been associated with the steel industry, having held engineering positions with the American Steel & Wire Company, and the Wickwire Spencer Steel Corporation. In 1925 he joined the Morgan Construction Company as a consultant, and later succeeded the late George H. Isley as manager of the combustion control department.

▲

Harry C. Ford died at Pittsburgh, Feb. 26. Since October, 1937, Mr. Ford had been superintendent of the production and shipping departments, Irvin works, Carnegie-Illinois Steel Corporation. Pittsburgh. Prior to assuming his new duties, he had been assistant to the general superintendent at the company's New Castle works. Mr. Ford began his connection with the company in 1903 at the Cambridge plant of American Sheet & Tin Plate Company, which later became a unit of Carnegie-Illinois Steel Corporation.

▲

Frank K. Buchanan, 57, for twenty years superintendent of the open hearth department, Edgewater Steel Company, Oakmont, Pennsylvania, died at his home in Oakmont, Feb. 10. Born in Johnstown, Pennsylvania, he worked in Lorain, Ohio, with Lorain Steel Company, and was later in the open-hearth department of Cambria Steel Company, at Johnstown, Pennsylvania. In 1916 he went into the open-hearth department of Andrews Steel Company, Newport, Kentucky, and in 1918 to the Edgewater Steel Company, where he remained until his death.

Developments

IN ROLLING FLAT STEEL PRODUCTS IN 1936

By STEPHEN BADLAM
Consulting Engineer
PITTSBURGH, PA.

Presented before the Annual Convention of the A. I. & S. E., Detroit, Michigan, September 22-25, 1936

INTRODUCTORY

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4 out of 5 used "Tool Steel" Gears – Wheels – Rolls in large quantities.

The fifth used a small lot.

"Tool Steel" is always a quality specification.

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GROWTH OF BROAD STRIP ROLLING

The growth of the Broad Strip Mill, since 1926, has been phenomenal. The productive capacity has been increased at a rate unprecedented in the history of the rolling mill, the average increase in capacity, for the ten years, being at the rate of 1,000,000 tons per year. The greatest increase has been in 1935 6–7, with approximately 2,500,000 tons added for each of the three years. The additions to the capacity, by years, is shown in the table following:

CONTINUOUS SHEET AND HOT BROAD STRIP MILLS

INCREASE ... YEARS

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1935-1936 CONSTRUCTION

...he five Hot Broad Strip Mills, reported as being ...der construction, last year, The Bethlehem Steel Co., 79″ Mill at Lackawanna, N. Y., went into operation on Dec. 29th., 1935. The Carnegie-Illinois Steel Co., 80″ Mill, at Gary, Ind., (previously reported as American Sheet & Tin Plate Co.,), on Mar. 1st. 1936, and the Great Lakes Steel Corp'n., 96″ Mill at Ecorse, Mich., (previously listed as 79″ Mill), on Mar. 23d., 1936. The Carnegie-Illinois Steel Co., 100″ Mill, at Homestead, Pa., went into operation on Dec. 3, 1936, and the Granite City Steel Co., 90″ mill, (previously reported as 84″ Mill), is expected to go into operation shortly.